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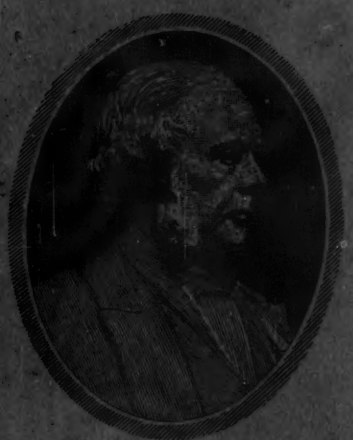

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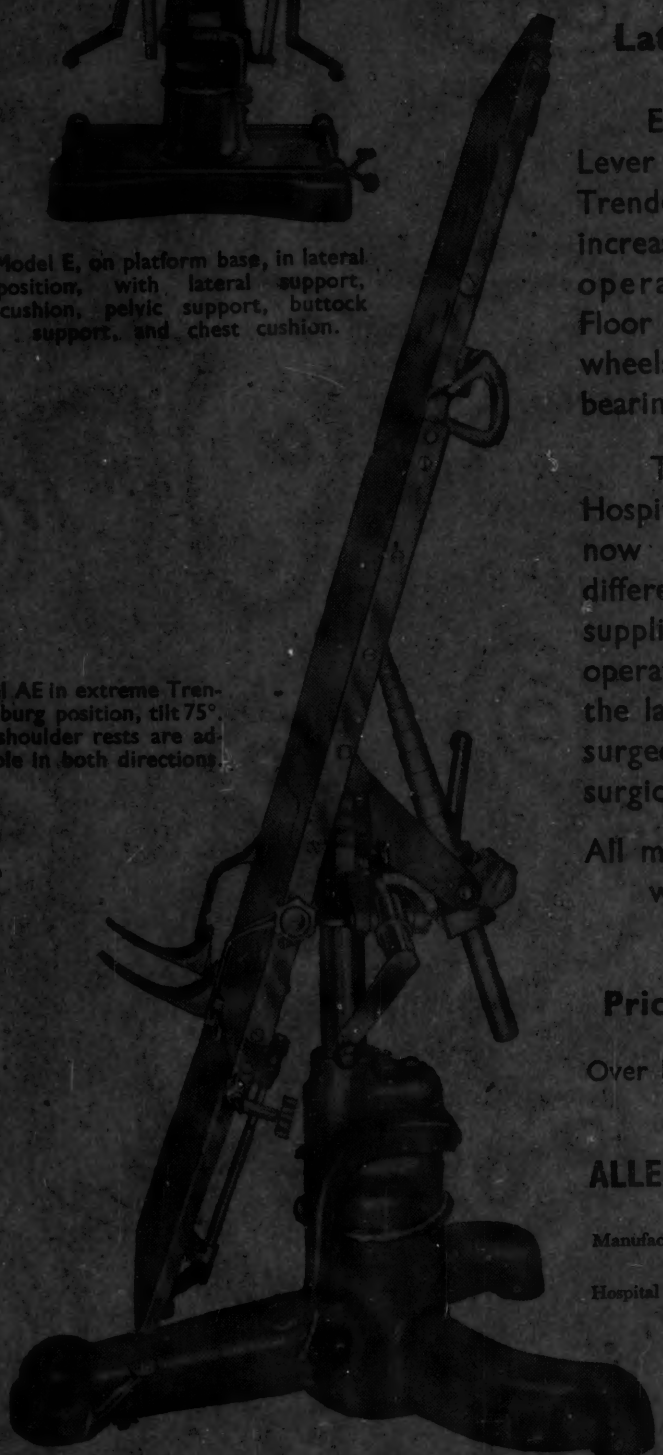

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THE
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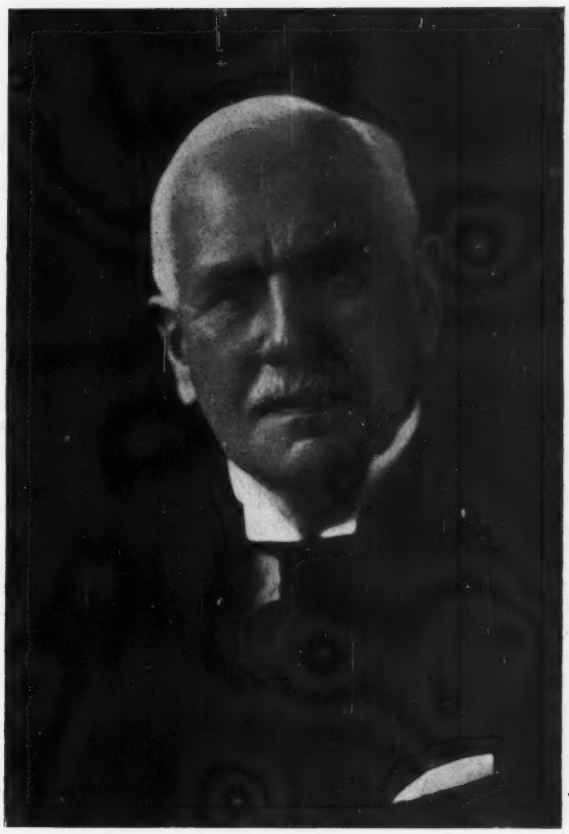
VOL. XXXI JULY, 1943 No. 121

In Memoriam

Sir W. ARBUTHNOT LANE, Bart., C.B.
(1856-1943)

WILLIAM ARBUTHNOT LANE died on Jan. 16 in his eighty-seventh year, and his passing removes another great figure from the surgical stage. He was born in Scotland on July 4, 1856, the eldest son of the late Brigade-Surgeon B. Lane, M.S., and was educated at Stanley House, Bridge of Allan. He entered at Guy's Hospital when a little over sixteen years of age, and so began a connexion with that institution which was to last in one way or another for seventy years. Living his active life as he did through the grand period of surgical adventure and advance, Lane was always among the foremost of the pioneers, and was a leader in introducing to London the precepts and practice of aseptic surgery. Throughout his active life his surgical work was distinguished by two characteristics: originality in conception and approach, and perfection in execution. No one who had watched him at work will gainsay that he must be ranked with the greatest technical operators of his, or probably any other, age. His gentleness of touch, his instant appreciation of the exact mechanical requirements in a bone operation, the ease with which he could operate by entirely instrumental means, and the effortless speed with which he completed the most formidable undertaking, were an artistic joy to the many who flocked to watch him.

His earliest work was done in the dissecting room at Guy's, where he already showed his interest in fractures. There he made many observations and wrote many papers on the changes undergone by the skeleton in consequence of the stresses and strains to which it is subjected by different occupations, illustrating his thesis by detailed studies of the anatomy of the coal heaver, the shoemaker, and the charwoman. He summed up his views in the statement, "we bear a simple mechanical relationship to our surroundings; any change in that relationship produces a corresponding alteration in our anatomy". To this statement he added another which was the basis of much of his later work and writings, namely, "Everything that nature does to meet such an alteration in our mechanical relationship to our surroundings tends to shorten our life." In



Sir W. ARBUTHNOT LANE, Bart., C.B.
1856—1943

1883, when a newly-appointed assistant surgeon to the Great Ormond Street Hospital for Children, he began to advocate and practice the removal of

part of a rib for the drainage of empyema, which brought down on him the wrath of many of the physicians of that time. This experience was to be the first of many similar ones, none of which, however, affected his views or practice. Lane thrived on criticism and opposition, and was wont to say that one should be thankful for one's enemies because they kept you stimulated. Extravasation of urine, the anatomy and pathology of the hip-joint, and laminectomy for the relief of paraplegia resulting from angular curvature of the spine, were some of the subjects on which he wrote at this time, and in 1891, impressed by some experimental work of the late Professor Starling, he began the practice of introducing normal saline into the circulation to replace blood lost by hæmorrhage. Shortly afterwards he turned his attention to the pyæmia resulting from disease of the middle ear, for which condition he was one of the first to undertake ligature of the internal jugular vein, and in 1893 papers on "The fallacy of the vertical foot-piece" and "the applicability of the angular gouge to the surgery of the skull", were evidence of the dissatisfaction which his mechanical instincts were beginning to feel at the current practices of bone surgery and which bore fruit in the same year in a paper on "the advantages of the steel screw in the treatment of ununited fractures". At about this time Lane devised his operation for cleft palate, and began advocating operation at a very early age. This was a great advance on the surgical procedure of the time, while the observations which he made on the effects of mouth breathing on the arch of the palate gained and retained general acceptance.

In about the year 1895 he began his work on the operative treatment of simple fractures. In appraising the value of this work when looked at with the experience of the present time, two things must be kept in mind: first, the poor general level of treatment which was usual at that time, which his repeated and insistant advocacy and practice of perfect anatomical reposition of the bone did so much to improve; and, secondly, the exquisite technique which he evolved for these operations, and which became and remains known all over the world as the Lane "no touch" technique. Many have emulated, but none have surpassed, the effortless perfection with which he performed these operations, and his method of purely instrumental handling remains to-day the ideal to be aimed at in all bone operations. The artistic mastery which Lane had in his medium produced, however, certain unfortunate results. Operations which his dexterity and superb technique made to appear simple were essayed by others not so well equipped in either respect, and with unfortunate results, and blame which should have attached to the performer was often transferred, ostrich like, to the method. Looking back, however, it appears that Lane's work on the treatment of fractures certainly marked a milestone in the progress of this branch of surgery, and to him must be given no small part of the credit for the present-day advances in operative orthopædic surgery.

Stimulated by the views of Metchnikoff, he next turned his attention, about 1902, to the surgery of the colon, and endeavoured to apply to it the principles he had laid down as governing the reactions of the bony skeleton to stresses and strains. His practice of complete colectomy for the condition which he termed chronic intestinal stasis, led at the time to much and often bitter controversy. While many of his views on this matter are now generally held to have been wrong, there are none who could doubt his sincerity, or fail to admire the brilliance of his technical achievement. Lane was one of the early advocates in London of the development of special departments in surgery, and did much to encourage their foundation, but his remark that the development of a special sense so often seemed to result in the loss of common sense, showed that he was well aware of the danger of over-specialization. During the first World War he served as a colonel in the Aldershot Command, and in conjunction with the late Professor Tonks had much to do with the establishment of the first plastic unit, so brilliantly developed by Sir Harold Gillies.

Arbuthnot Lane was a man whose main interest in life was surgery. Possessed of a restless energy and with an enormous capacity for work, he could ill tolerate the prospect of idleness which advancing years held out. He therefore turned his attention to popularizing those principles of health in which he believed, and which he held should be more widely known. He founded the "New Health" Society, and with that utter disregard of criticism which had always been his characteristic, propounded his views in ways and in places which brought him into opposition with established authority. Tempestuous as was his professional life (and Lane himself was a vigorous and hard-hitting opponent), he was personally the most kind hearted and gentle of men, loyal to a degree to those who had gained his affection. His loyalty continued even after some of his swans had turned out to be geese, and he was always willing and ready to help those, and there were many, who came to him for aid.

Sir Arbuthnot was a most generous and hospitable host, and was never happier than when entertaining, at his own house, his friends, and the many and distinguished visitors from America and Europe who flocked to watch his work. He in turn, on his many visits to the United States, received in full the honour and acclamation which were his due. He was never happy as lecturer or speaker, but he had in full measure that greatest attribute of the teacher, the ability to inspire enthusiasm and to stimulate interest in all those who came under his influence. Punctuality with Lane was invariable; he considered it an essential of politeness, and however busy

he might be, his hospital visits were meticulously observed. He was created a baronet in 1913, and was also a Chevalier de la Légion d'Honneur.

He was married twice, firstly, in 1884, to Charlotte, daughter of John Briscoe, with whom he celebrated his golden wedding, and secondly, to Jane, daughter of the late Mr. N. Mutch.

He leaves a son, William Arbuthnot, who succeeds to the title, and three daughters.

THE ROLE OF BILE IN DUODENAL REGURGITATION*

By L. R. BRAITHWAITE

"EVERY theory of the course of events in nature is necessarily based on some process of simplification of the phenomena, and is to some extent, therefore a fairy tale". (Sir Napier Shaw.)

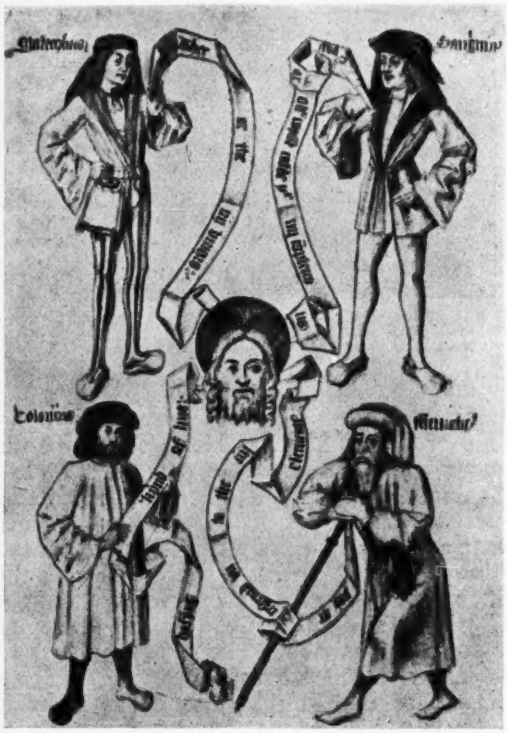


FIG. 1.—Illustrating the "Four Temperaments" from the Guild Book of the Barber-Surgeons of York, now in the British Museum. The figure was prepared about A.D. 1500. Above, to the left, is the *Melancholy* man, and to the right the *Sanguine*. Below, to the left, is the *Choleric* man, and to the right the *Phlegmatic*. On the scroll work is written in English, "Ther ar the iiij umors, thath ar oderwysse calde the iiij complecconis that ar resceuid un to the iiij elementis, Hafyng the kynd of humors", which may be rendered, "There are the 4 humours, that are otherwise called the 4 complexions, that are received unto the 4 elements, having the nature of humours".

The history of bile is a long and fascinating story, it was sung in verse and recounted in prose from early times; maybe the striking colour and bitter taste impressed it upon both ancients and moderns; perhaps the fact that its appearance was so often synonymous with sickness created profound interest and dread. Singer says: "In mediæval parlance the Complexio, Temperamentum or Constituto was a Mistio of four humours, Sanguis, Phlegma, Melancholia and Choler—i.e., blood, phlegm, black bile, and yellow bile". Galen (A.D. 163) attributes to Hippocrates (430 B.C.) four humours: (1) Blood (like air) was hot and moist; (2) Phlegm (like water) was cold and moist; (3) Yellow Bile (like fire) was hot and dry; (4) Black Bile (like earth) was cold and dry.

Galen says: "Yellow bile, summer and fire, are hot and dry; melancholy humour, earth and autumn, are dry and cold". In youth there is an abundance of blood, in early manhood of yellow bile, in middle and declining age of black bile, in old age of phlegm.

Milton describes old age as cold and dry, Galen as cold and moist. Galen regarded the

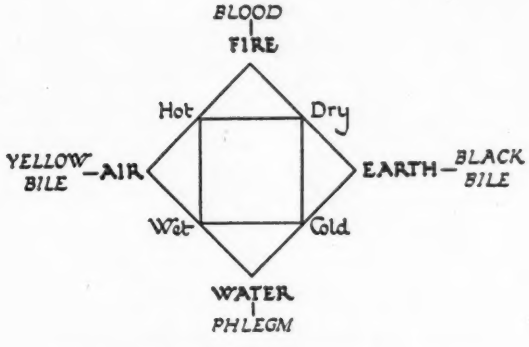


FIG. 2.—The four *Elements* in association with the four *Humors* and the four *Qualities*.

spleen as helping to purify the blood manufactured by the liver, by secreting the black and melancholic juices; this black bile or melancholy humour was thought to cause not only melancholy but anger and ill temper, hence the origin of 'spleen' as a synonym for 'anger'. It is amazing that in the same period the spleen should be considered to be the seat of laughter.

Burton says: "Melancholy cold and dry, thick black and sour, begotten of the more feculent part of nourishment and purged from the spleen, is a bridle to the other two hot humours, blood and

* The Bradshaw Lecture, given at the Royal College of Surgeons on Nov. 12, 1942.

choler—preserving them in the blood and nourishing the bones ".

Prior, in his poem, " Alma : or the Progress of the Mind ", thus describes the physiological functions of the liver :—

> But let your friends in verse suppose
> What ne'er shall be allowed in prose ;
> Anatomists can make it clear
> The liver minds its own affair ;
> Kindly supplies our public uses,
> And parts and strains the vital juices ;
> Still lays some useful bile aside
> To tinge the chyle's insipid tide ;
> Else we should want both bile and satire,
> And all be burst with pure good nature.

The belief in the presence of two kinds of bile was universal in ancient and medieval times ; black bile was manufactured by the spleen and conveyed to the stomach, while yellow or red bile came from the liver. Mondino (Mundinus), in the *Fasciculo di Medicina, Venia*, 1493, says (p. 72) : " The gall-bladder was made to attract *red* superfluous bile from the liver and to expel it to the guts ". The liver was regarded as the

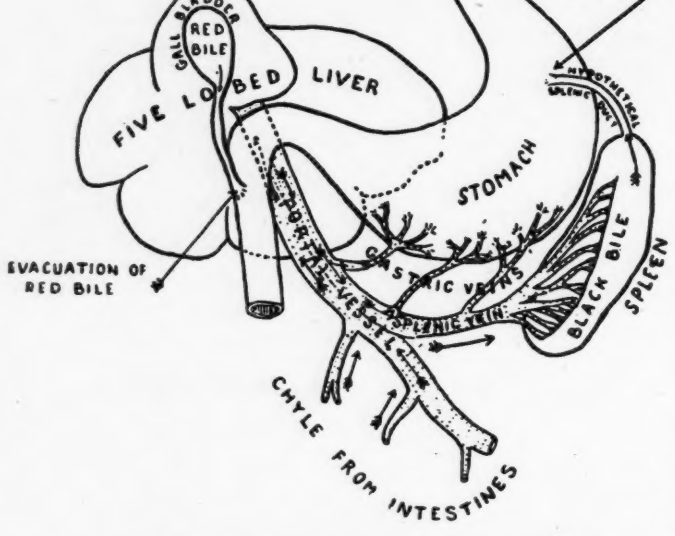


FIG. 3.—The medieval view of the physiology of the portal system. The portal vessel brings chyle from the intestines to the five-lobed liver. Red bile is evacuated from the liver by the bile-duct into the duodenum. Blood is sent from the liver to the spleen via the splenic vein. Black bile (Melancholy) is evacuated into the stomach either by a hypothetical duct near the cardiac end of the stomach or by the gastric veins. (*Singer.*)

factory of the blood until the time of Harvey and after—" the substance of the liver is solidified blood ". The splenic vein is described (p. 70) as having " one branch reaching to near the orifice of the stomach beareth the melancholy which softly floweth to the mouth of the stomach to excite the appetite ".

Singer says : " It is hardly the case that bile had a bad reputation, the theory of disease was (and remained almost until living memory) that people were of different constitutional types commonly distinguished as four, namely, the ' sanguine ', the ' phlegmatic ', the ' melancholic ', and the ' choleric ', corresponding to the four

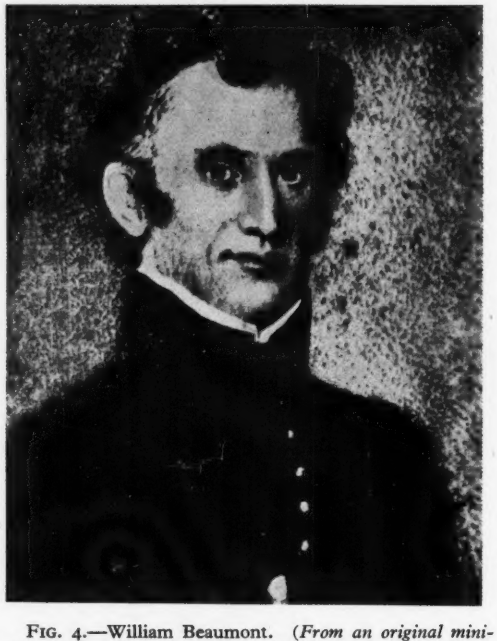


FIG. 4.—William Beaumont. (*From an original miniature in the possession of Miss Sophie Beaumont, of Green Bay, Wisconsin.*)

humours. These types were conditioned by a Mistio or Complexio, in which one or the other humour was in excess. It was, of course, a bad thing—a bad mistio—to have too much choler, but it was also a bad mistio to have too much phlegma. Our modern terms—' temperament ', ' constitution ', ' ill-humour ', etc., have all their roots in this theory ".

The humoral theory held almost undisputed sway until the time of Virchow.

I am not concerned to-day with the usual functions of bile in the intestine as related in modern text-books, but rather with bile as the ancients understood it, that is, in the stomach.

Magendie was one of the first investigators to draw attention to the presence of obvious bile in the gastric contents, and considered it as of normal rather than of pathological significance. " I believe [he said] that in certain morbid conditions the bile is *not* introduced into this organ [the stomach] ".

However, the first really important observations by reason of their accuracy, their number, and the detail of their description were made by William Beaumont in 1833.

This story is one of romantic interest and profound importance in gastric physiology and will, I think, bear short repetition. In the words of Osler : " On the morning of June 6, 1822, a young French Canadian was standing in the

Company's store where one of the party was holding a shotgun (not a musket) which was accidentally discharged, the whole charge entering St. Martin's body. The muzzle was not over three feet from him—I think not more than two. The wadding entered, as well as pieces of his clothing; his shirt took fire; he fell, as we supposed, dead". Dr. Beaumont, the surgeon of the fort, was immediately sent for and reached the wounded man in a very short time, probably three mintues. After the doctor had extracted part of the shot, together with pieces of clothing, and dressed his wound carefully, he left him remarking: "The man cannot live thirty-six hours; I will come and see him by and by"

But St. Martin *did* live, with a gastric fistula fortuitously fitted with a valve of mucosa which prevented leakage. Beaumont, finding St. Martin declared "a common pauper", and as such about to be transported to his native country in Lower Canada 1500 miles away, received him into his own house, "kept, nursed, medically and surgically treated and sustained him" for two years before beginning his experiments in May, 1825.

In the course of Beaumont's movements as an Army surgeon he took St. Martin with him, but occasionally the patient escaped, only to be sought out and brought back. The experiments

FIG. 5.—Beaumont collecting a sample of fluid from St. Martin's gastric fistula.

went on and off until November, 1833, when St. Martin was 28 years of age and entered the United States army. Although later great efforts were made to induce him to submit to further experiments he refused, but travelled the United States and some parts of Europe exhibiting his wound. The Medical Society of London raised £300 to £400 as an inducement to come to England. It would appear that St. Martin remained in very good health up to his death in 1880 at the age of 83, although he occasionally "took to drink". The family resisted all requests—most pressing as they were—on the part of the medical profession for an autopsy, and kept the body at home much longer than usual and during a spell of hot weather, so as to allow decomposition to set in and baffle, as they thought, the doctors of the surrounding country and others.

For the purpose of this lecture I have extracted almost all the observations made by Beaumont on biliary regurgitation:—

Page 21: "On laying him, i.e., St. Martin, horizontally on his back, pressing the hand upon the hepatic region, agitating a little, and at the same time turning him to the left side, bright yellow bile appears to flow freely through the pylorus, and passes out through the tube. Sometimes it is mixed with gastric juice, without this operation. This is, however, seldom the case, unless it has been excited by some other cause."

Page 87: "Fear and anger check its secretion (that is, gastric juice) also the latter causes an influx of bile into the stomach which impairs its solvent properties."

Page 90: "From the circumstance that the introduction of sponge, tubes, pebbles, etc., by Spallazani and others excited the discharge of the gastric juice and from the fact that the gum-elastic tube in my experiments produced the same effect when the stomach was empty and healthy, I infer that the first effect of aliment on the stomach is one of irritation of the gastric papillæ."

Page 95: "Bile is not essential to chymification—it is seldom found in the stomach except under peculiar circumstances. I have observed that when the use of fat or oily food has been persevered in for some time, there is generally the presence of bile in the gastric fluid. Whether this be a pathological phenomenon induced by the peculiarly indigestible nature of oily food, or whether it be a provision of nature to assist in the chymification of this particular kind of diet, I have not yet satisfied myself. Oil is affected by gastric juice with considerable difficulty. The alkaline properties of bile may render it more susceptible of solution in this fluid by altering its chemical character. Irritation of the pyloric end of the stomach with the end of the elastic tube, or the bulb of the thermometer, generally occasions a flow of bile into this organ. External agitation by kneading with the hand on the right side over the region of the liver and pylorus produces the same effect. It may be laid down as a general rule, however, subject to the exceptions above mentioned, that bile is not necessary 'to the chym' of food in the stomach. There can hardly be a greater mistake than that made by Magendie that bile is present in the stomach in health conditions and absent in unhealthy; with the exceptions that I have mentioned, it is never found in the gastric cavity in a state of health and it is only in 'certain morbid conditions' that it is found there.

Expt. 32: March 12, 9 o'clock breakfast on fat pork, bread and potatoes, one hour afterwards examined contents resembling thick porridge. At 1 p.m. —four hours after eating—took out a portion completely chymous, considerably tinged with bile. This I supposed to be the effect of violent anger which

occurred about the time of taking out this parcel. When bile is so found, except under peculiar circumstances of diet, it may generally be regarded as an indication of either mental or corporeal disease and may be considered as a foreign and offending substance in that organ. I believe its effect is to change the properties of chyme, alter its homogeneous quality, and retard or otherwise disturb its due egress into its destined receptacle, the duodenum.

ix. July 28. ". . . St. Martin has been drinking ardent spirits, pretty freely, for eight or ten days past . . ."

xi. August 2. ". . . extracted one ounce of gastric fluids—consisting of unusual proportions of vitiated mucus, saliva, and some bile, tinged slightly with blood, appearing to exude from the surface of the erythema, and aphthous patches. . . ."

Following Beaumont are several instances of the investigation of gastric function in subjects with gastrostomy openings, but none of them is of great significance, by comparison, until the important series of observations made by Carlson in Chicago from 1912 onwards. "Carlson's man", a Bohemian who had been given a gastrostomy opening, following a cicatricial closure of the œsophagus, was in some respects a more reliable subject than Alexis St. Martin. He was employed as a laboratory servant, and, therefore, was under continuous observation, and the gastrostomy opening, because it was achieved surgically, presented no source of constant irritation as it did to St. Martin.

Carlson reported that about 50 per cent of the *resting* gastric contents collected in the morning contained bile, but that it was rarely present in samples collected during the course of the day. During the strong contractions of the stomach occurring in fasting periods—the "hunger contractions"—bile frequently entered the gastric cavity.

Because it was thought that the investigation of gastric function by a gastrostomy opening was a superior method to any in which flexible tubes or catheters were introduced into the stomach through the mouth and the œsophagus, it was held that, although Spallazani and Magendie, amongst others, had obtained gastric juice containing bile, the regurgitation was most likely to be consequent upon the irritation caused by the introduction of the collecting tube.

The introduction of the Einhorn and the Rehfuss method of intubation made it possible to investigate the course of gastric digestion and the contents of the stomach, particularly in the practised subject, with little disturbance to the subject. Under these conditions the presence of bile is frequently observed. Bennett and Ryle (1921), reporting on a series of 100 students, stated that bile was present in the resting juice in 50 per cent of cases, and occurred in about 30 per cent during the course of the digestion of the test-meal.

It may be concluded that although the earlier observers, such as Magendie, had the opinion that the presence of bile in the stomach was abnormal, the work of more recent investigators, using the stomach tube and the fractional test-meal technique, has led to a revision of views. It is now accepted that *resting* gastric juice frequently contains bile and that it may appear in a fair proportion of cases during the process of gastric digestion.

The introduction of the modern form of gastroscope has facilitated observations of the gastric cavity, although it is doubtful whether much importance should be attached to movements observed during gastroscopy, because of the influence of the mental reactions of the subject. Schindler (1937), however, refers to the frequent presence of bile in the *resting* stomach, describing a "mucus lake" which may form in the most dependent part of the greater curvature: "The shore is often steep and the appearance is that of a green mountainous lake—a resemblance resulting from the regurgitated bile".

In dogs, according to Wilhelmj (1936), bile is almost always present in the gastric contents.

THE MECHANISM OF BILIARY REGURGITATION

It must be accepted that bile found in the stomach has passed there by regurgitation of duodenal contents. The presence of bile in the stomach is usually taken as evidence of regurgitation, but regurgitation may occur without obvious presence of bile in the stomach. Shay, Katz, and Schloss (1932) followed regurgitation of a dyestuff into the stomach from the duodenum, using as indicator, bromsulphalein, which is eliminated in the bile. On several occasions they were able to demonstrate the presence of the dyestuff in the gastric contents when, apparently, there was no bile.

The conditions necessary for regurgitation into the stomach are: (*a*) intraduodenal pressure greater than intragastric pressure; (*b*) a patent pyloric opening, or a pressure gradient between duodenum and stomach sufficient to force the pylorus open.

Little is known about the type of muscular or nervous action that brings about this backflow.

Rhythmic segmenting movements of the duodenum have been held responsible in animals (Hicks and Visher, 1915), while Alvarez (1940) describes "strong reverse waves in the second portion of the duodenum throwing the barium mixture back towards the pylorus, but they seemed to be but an exaggeration of the normal rhythmic to-and-fro movements".

Regurgitation into the resting stomach seems to be fairly common, and in the conditions holding (empty stomach with low tone, intestinal activity, and open pylorus), the gradient, intestine to stomach, would be suitable for its occurrence. It is also common during the digestion of a meal with a high fat content. In this condition stomach movements and intragastric pressure are known to be reduced. There is little information about the state of the pylorus, but it seems likely

that the slow emptying of the stomach may be due to lack of intragastric pressure rather than a closed pylorus.

Opinions about the control of the pylorus are less rigid than formerly as it has become clearer that a hypothesis of a simple method of control according to the relative acidities of the gastric and duodenal contents is inadequate. The modern view (Alvarez, 1940), while not denying that the pyloric sphincter can stand as a gateway between stomach and duodenum, stresses the relative muscular activity of stomach, duodenum, and probably jejunum, in establishing intravisceral pressures and pressure gradients between the different parts of the alimentary tract. Thus, activity of the duodenum can hold back material about to leave the stomach whatever the condition of the pylorus, whereas an increase in the tone and activity of the stomach will tend to hasten its emptying. These mechanical factors are perhaps the most important ones in controlling the passage of material through the pylorus. Crider and Thomas (1937) state that the rate of stomach emptying is uninfluenced when a rubber tube is inserted into the pylorus to keep it open.

It may probably be accepted that the pylorus is open in the resting stomach. Bland fluids are known to pass almost immediately into the duodenum and Schindler (1937), observing with the gastroscope, finds the pylorus—" a dark round hole "—usually open. When solid material passes into the stomach, the tone of the viscus is increased and peristaltic movements are initiated. The tone of the pylorus is increased and it may close. The closure may only take place, or be made more complete, when a wave of peristalsis sweeps over the antrum. Schindler describes contractions occurring in the antrum of the empty stomach where, as the wave passing over the antrum approaches the pylorus, the latter " becomes smaller, and finally closes completely, often expelling energetically, intestinal juice mixed with air bubbles ". The pylorus opens before the next wave of contraction passes over the antrum.

To sum up, it appears on the whole that bile does regurgitate in perfectly healthy individuals, and that under gastric conditions such as local irritation due to the presence of a tube or to the presence of inflammation, such a regurgitation is to be expected.

THE SIGNIFICANCE OF BILIARY REGURGITATION

It is generally agreed that man secretes 500 c.c. of bile in 24 hours and from 200 to 500 c.c. of pancreatic juice.

Regurgitation of a fluid containing bile is, of course, synonymous with duodenal regurgitation. The fact of duodenal regurgitation carries with it the possibility of any constituent of the duodenal contents affecting those of the stomach. The ones likely to be of physiological significance are (*a*) pancreatic enzymes, (b) bile-salts, (*c*) bile-pigments, and (*d*) alkali (chiefly $NaHCO_3$,) present in the pancreatic secretion and in bile.

Beaumont, who associated the presence of bile in the stomach with the intake of a fatty meal, held that bile was concerned in the digestion of fat, which took place largely in the stomach. By experiment he endeavoured to support his hypothesis, showing that gastric juice to which he had added bile was able partially to digest fat *in vitro* ; gastric juice alone was unable to bring about this action. In assessing the value of Beaumont's work it must be remembered that the existence of pancreatic lipase was not demonstrated until the investigations of Claude Bernard (1849) on pancreatic juice. At the present time little attention is paid to the possibility of gastric digestion of fat, although there is some evidence of a gastric lipase, and if duodenal regurgitation occurs to any significant extent, then, presumably, pancreatic lipase will enter the stomach. Even so, it is unlikely to be active, because the reaction of the stomach contents is rarely brought to the necessary state of alkalinity. This argument, although applied specifically to fats, disposes of the likelihood of any pancreatic enzymes being effective if regurgitated into the stomach.

The bile pigments cannot be regarded as having any physiological significance in the stomach.

Chief interest in regurgitation has been directed to the possible part played by the pancreatic juice and the bile in partially, or completely, neutralizing the gastric contents. The gradual rise and usual fall of gastric acidity following the intake of food had been noticed both in cases with gastrostomy openings and in stomach tube experiments. In man, the normal acidity curve reaches its maximum in about an hour and then commences to decline. Pavlov (1910), from experiments on exteriorized gastric pouches in dogs, had the opinion that the gastric mucosa secreted HCl up to a constant concentration. When there was an accumulation in the stomach he noticed a diminution of further secretion of the acid. " With the same dogs we also discovered a new form of autoregulation on the part of the stomach, which concerns the secretion of hydrochloric acid. It appears that the acid prevents the further secretion of gastric juice when it has accumulated in any considerable quantity in the cavity of the organ."

A similar inhibitory effect on the secretion of hydrochloric acid was observed when acids, other than hydrochloric, were introduced into the stomach cavity. On the basis of these and similar experiments, the stomach was regarded as having intrinsic control of the acidity of its contents. More recently support has been given to the hypothesis by the work of MacLean and Griffiths (1928), Wilhelmj and his associates (1936, 1937), and Goldberg (1932), who all made observations on animals with gastric pouches. On

the other hand, Bolton and Goodhart (1931) could find no evidence to support it, but their experiments differed from those of other workers in the use of pilocarpine as a stimulus to secretion.

A hypothesis in contradiction to the autoregulation of acidity postulated by Pavlov was suggested by Boldyreff (1907, 1915) and requires carefu! examination, because of the important role attributed to biliary and pancreatic regurgitation. Boldyreff criticized the drawing of conclusions regarding the control of the acidity of stomach contents from experiments on gastric pouches and made a distinction between the acidity of gastric juice and that of stomach contents. While accepting the possibility of autoregulation, he insisted that additional processes might operate, in the intact stomach, to effect reduction of acidity. Amongst others, he considered dilution of gastric secretion and neutralization by saliva, mixture with alkaline mucus or pyloric juice, the dilution of the acid by the secretion of a special diluting fluid—*Verdunnungssaft*—and neutralization by regurgitation of pancreatic secretion and bile. Boldyreff considered the last two of these the most probable cause of the reduction of gastric acidity and showed that the pancreatic juice had the greatest alkalinity of any of the secretions considered. Experiments were performed in which HCl was introduced into the stomach and the reduction of acidity observed. That the reduction was due to neutralization, rather than dilution, was demonstrated by determination of the chlorine concentration. By performing experiments on dogs in which the effects of saliva, pancreatic juice, hepatic bile, and bladder bile were successively prevented by suitable operative procedures, it was shown that reduction in gastric acidity occurred most rapidly when the pancreatic secretion was free to enter the duodenum. But the idea of an intrinsic regulation of gastric acidity was also accepted. Cathcart (1911) confirmed Boldyreff's findings with regard to the importance of duodenal regurgitation, while Spencer and his co-workers (1916), in experiments upon the human subject, showed by examining stomach contents for tryptic activity that duodenal regurgitation commonly occurred, and suggested that it was the chief factor in reducing gastric acidity. Bennett and Ryle (1921) supported the hypothesis of Boldyreff. A similar finding was made by Bolton and Goodhart (1922), who associated the fall in the concentration of free HCl in the gastric contents with a rise in the inorganic chloride concentration and attributed it to neutralization by base in the duodenal regurgitation.

Despite these experiments, which seem to give convincing support to the hypothesis of duodenal regurgitation, the question does not appear to be settled beyond doubt, for Baird, Campbell, and Hern (1924) found, although the number of cases examined was not large, the usual type of acidity curves, for fractional test-meals, in individuals from whom the duodenal contents were continually aspirated. And MacLagan (1934), who made a statistical analysis of the results of 389 consecutive fractional test-meals, could find no significant relationship between the presence of bile and the reduction of acidity. Thus, out of 102 cases showing distinct peaks in the acidity curves only 19 had bile in the gastric contents at a time corresponding to the change in acidity, while in 83 cases bile was present wholly before or after the fall in acidity had commenced. Neither did the presence or absence of bile seem to affect the arrangements of the cases into classes based on the rate of change and degree of acidity. Baird, Campbell, and Hern, and MacLagan are inclined to attribute greater neutralizing power to the pyloric secretions than are former investigators.

With regard to the role of duodenal regurgitation, it seems possible to take a more positive attitude than that of MacLean (1928), who wrote: "duodenal regurgitation when it occurs is an accident . . . it is in no way connected with the reduction of HCl and the associated rise in neutral chloride which occurs in digestion". Duodenal regurgitation in the resting phase of the stomach occurs in the majority of a series of subjects (Rehfuss and Hawk, 1921; MacLagan, 1934) and often in one individual (Beaumont, 1833; Carlson, 1912). This accumulation in the stomach will affect the development of acidity in the initial stages of digestion. Although a description of regulation of acidity in the later stages is more conjectural, it seems undeniable that in some cases the decline in acidity is associated with the appearance of bile in the stomach. In other cases the pyloric secretions may play a larger part, and in any case there has been a tendency to assume that the duodenal fluid is of constant composition—which it certainly is not: it is a mixture of pancreatic juice, bile, and duodenal secretion; the composition of bile is very variable, alters in amount according to the type of foodstuff in the gastro-intestinal tract, and the pigments, usually taken as an indication of regurgitation, are of no significance for neutralization. It is during the digestion of fatty meals that regurgitation may be most significant. The tone and intensity of movements in the stomach is known to be low, while duodenal activity may be increased. The secretion of bile, and probably pancreatic juice, is augmented. The emptying time of the stomach is lengthened, and although little experimental work on the relationship of gastric acidity and fat content has been done, it seems certain that chyme entering the duodenum will be already neutral in reaction and favourable for fat digestion.

In common with my contemporaries I grew to fear bilious vomiting. I had seen it in the vicious circle following a long-loop gastro-enterostomy and had watched it in all forms of intestinal obstruction. I had noted it in acute peritonitis and recognized it in many toxic conditions, both general and local.

In obstructive conditions I understood it, but it was long before I appreciated that bilious vomiting without obstruction was not so much due to bile in the stomach but occurred *in spite of it*, that is, *bile was beneficent and not lethal*. I knew, of course, that cholecyst-gastrostomy for pancreatic disease did not cause vomiting, but in spite of that I had the impression that bile was a gastric irritant.

On Nov. 27, 1912, I was confronted with an entirely unexpected problem under the following circumstances: The patient, matron of a local hospital, was seized with acute intestinal obstruction due to a carcinoma in the splenic flexure. I did a cæcostomy and assured myself there were no palpable secondary deposits in liver or pelvis. After five weeks I again operated for removal of

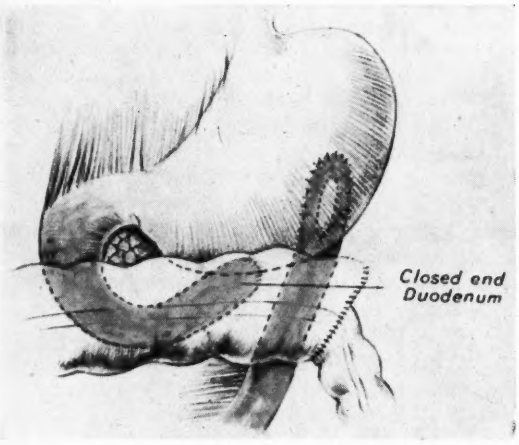


FIG. 6.—Showing the transverse and descending colon united, and the anastomosis of the ileum with the posterior wall of the stomach.

the growth; it was easily found and was the size of a Tangerine orange; it occupied a position just above the splenic flexure, in the extreme left of the transverse colon. The omentum was adherent to it, and on trying to lift it out of the abdomen, the growth was found to be tightly bound down to the deeper structures.

Careful investigation revealed the fact that by reason of a downward and backward rotation of the colon, the growth had extended to, and was involving, the highest part of the jejunum at the duodenal flexure, and was invading the upper half of its circumference at this point.

It was decided to resect the duodenal flexure with the portion of the large bowel containing the growth, and its lymphatic shed. I found it impossible to perform either an end-to-end or a lateral approximation of the duodenum to the jejunum, because there is not a complete investment of the duodenum by peritoneum at this point, and because there was not sufficient material in the duodenum available, for such stitching purposes. The divided end of the duodenum was therefore closed by three rows of Pagenstecker sutures, drawing over the stump a double layer of parietal peritoneum. Posterior gastro-jejunostomy was quickly performed, the upper part of the jejunum, well below the closed divided end, being utilized. The colon was reconstituted. (*Fig.* 6.)

Except for occasionally vomiting a little bile, she made constant improvement. From May 1 to May 18, 1913, she was in the General Infirmary at Leeds for the purpose of observation. The bowels were acting normally, and there was no sign of recurrence of the growth. An X-ray examination was made by Dr. Rowden, who reported, "The gastro-enterostomy opening is quite patent; the stomach is almost empty in 4½ hours; no food is seen in the duodenum".

She left the district in June, and was reported January, 1914, as "doing well".

Food had to be carefully selected, and nothing in the nature of a heavy mass, unmixed with fluid, was ever taken. Digestion was comparatively comfortable, except during an attack of eructation and vomiting, when milk and soda alone was accepted.

I was astonished to find that vomiting was not incessant; the whole of the bile and pancreatic juice was passing backwards into the stomach and yet giving rise to little trouble. I then discovered that Moynihan in 1901 had reported a case of traumatic rupture of the duodenojejunal junction treated in exactly the same way except that the gastrojejunostomy was made with a Murphy button which ulcerated through the duodenum and killed the patient (a boy aged 6) on the 104th day after operation. I further found that in 1911 my colleague, Mr. Collinson, had operated on a girl aged 17 for a retroperitoneal growth. In the course of the operation the duodenojejunal junction had to be partially removed and a similar operation to Moynihan's and my own had to be performed.

Neither of these cases had vomiting—bilious or otherwise; so far as we are aware Collinson's case is still alive; mine died from secondaries in the liver three years after operation.

I know others have done this operation in man and in animals, and with similar immediate results (Kelling, 1900; Chlumskij, 1898; Rosenberg, 1898; Ledderhouse, 1899; and Kolbing, 1902).

And so it became perfectly clear that bile in the stomach does not cause vomiting so long as it can easily get out; in 'vicious-circle' vomiting it cannot.

The experiments of Beaumont showed that under conditions already described bile entered the stomach. They proved that an irritation such as the presence of a tube would induce it, and that an inflammation (gastritis) would produce it. *We* know that the presence of a tube, either a Rehfuss or a gastroscope, ensures it, and we deduce that any investigation of gastric bile (or duodenal contents) withdrawn by tube must be fallacious.

I recently carried out investigations on gastric fistulæ without tube, and, thanks to the kindness of my colleague, Mr. Allison, I have recently caused observation to be made on three cases of gastric fistula occurring temporarily during the course of operations for removal of carcinoma in the lower œsophagus. They show that in these

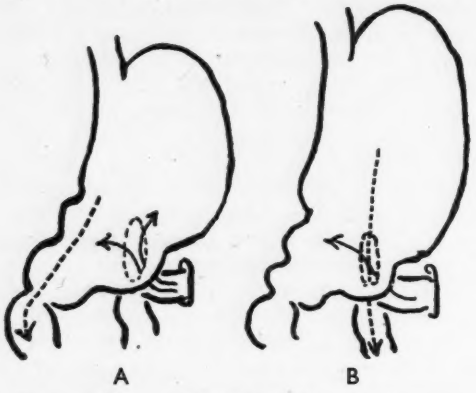


FIG. 7.—A, Successful symptomatic gastro-enterostomy for duodenal ulcer, without pyloric stenosis (Rowden). B, Modern conception of similar case.

cases bile is a constituent of stomach contents in small quantity from two to two and a half hours after food, and that only traces of pancreatic juice can be found.

Some time about 1920 my friend, Dr. Rowden, of Leeds, always direct and emphatic in speech, pointed out to Moynihan and myself that in his vast experience of X-ray examination of stomachs he had found that the best symptomatic results following gastro-enterostomy for duodenal ulcer without stenosis were exactly those cases where nothing passed through the anastomosis from above downwards, but free regurgitation was taking place from jejunum to stomach. Such a statement (by no means universally approved) coming from a man like Rowden made a great impression on me, and I began to wonder whether the influence of bile in the stomach could possibly account for it—*if it could*, then a gastro-enterostomy except where pyloric obstruction was present, was not the right operation. I had myself been the subject of gastro-enterostomy for duodenal ulcer; my own experience, and that of many of my patients, had made me unhappy about its complete success.

Could it be that the pyloric spasm known to be present with an active duodenal or gastric ulcer prevented reflux of bile and pancreatic juice which was in some way required for the prevention or cure of either gastric or duodenal ulcer?

With these things in my mind I began to try and find out what influence bile alone could have. I recognized it as normally present between meals. I persuaded a patient whose normal Rehfuss charts and radiographs I already had, to swallow ox bile in capsule and otherwise, in varying dilution and quantity, 2 hours after food. It caused nausea and sometimes diarrhœa, but in a few days tolerance was established, and investigations were carried on, once a day for six days. It was found that with a dose of 10 c.c. of 50 per cent diluted bile two things happened: (1) There was apparently a diminution of gastric peristalsis, and (2) There was slight but definite diminution of gastric acidity. These two things produce a quiet stomach and protect it between meals. Was it not likely that this might be the reason for normal biliary regurgitation?

I argued that a bad appendix or some other irritant in the ileocæcal area would produce pyloric spasm and congestion which would cause gastric juice, of increased acidity, to collect in the stomach and at the same time prevent normal biliary regurgitation.

It would, therefore, be important to notice the " bile line " on a Rehfuss chart with peculiar interest. To explain why a pyloric spasm resulting from irritation derived from the right iliac fossa should apparently and in the presence of the much more severe lesion, i.e., ulcer, relax and allow *more and more* bile to enter the stomach is difficult. Can it be that the call for more bile is imperative and overwhelming? Is it the response to trauma which Beaumont described?

I think there is no doubt that the Rehfuss charts are reliable in indicating roughly that: (1) Given suitable symptoms, bile absent or delayed beyond 2 hours may mean pyloric spasm

FIG. 8.—A, Two hours after meal, pylorus open. Slight biliary regurgitation. B, Pyloric spasm (gastric ulcer). Great pressure of bile forces pyloric spasm.

or obstruction; and (2) Bile in the presence of 'gastric' symptoms *all the time* means a great effort to counteract a serious simple lesion or the presence of a gastric carcinoma propping open the pylorus.

Because full biliary regurgitation would be impossible in the presence of pyloric spasm I argued that a gastric erosion setting up such a spasm might become a gastric ulcer. The fact that pyloric spasm would not wholly prevent bile reaching the duodenal side of the pylorus by regurgitation does not invalidate my theory of the cause of *duodenal* ulcer in that it would not greatly influence the immediate cause of the ulcer, i.e., *gastric* hyperacidity.

Would not a free flow of bile, automatically controlled, and administered by a cholecyst-gastrostomy, be beneficial in such conditions? I did not know that it had already been suggested.

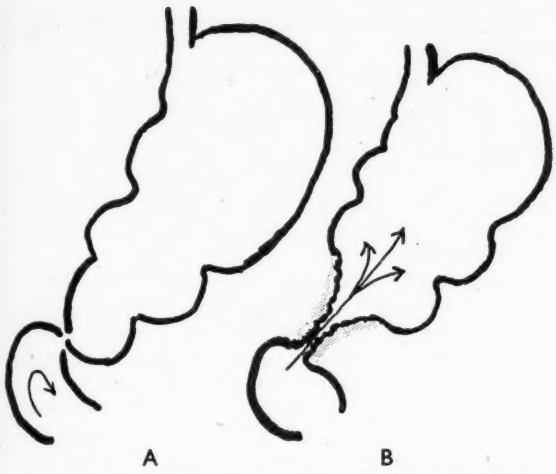


FIG. 9.—A, Simple pyloric stenosis, bile absent or slight. B, Carcinoma of pylorus, bile in great quantity.

Dr. W. Wayne Babcock was probably the first surgeon to apply the supposed virtues of bile to the treatment of gastric ulcer and to suggest its use for persistent hyperacidity and pyloric spasm. He says: "Contrary to conventional opinion, bile is a normal fluid in the stomach and plays an important but poorly recognized part in gastric digestion. Its entrance into the stomach does not produce nausea or discomfort, but is associated with the cessation of gastric digestion and the arrest of motor activity of the stomach. Thus, at the completion of each period of gastric digestion the pylorus normally relaxes, bile flows into the stomach and neutralizes and permanently arrests the activity of the acid pepsin in the chyme. The antrum of the stomach, which has felt the brunt of the irritation of gastric digestion, is coated with a protective film of the alkaline mucilaginous fluid, and the peristaltic movements of the stomach cease. We would term bile, therefore, the normal resting medium of the stomach. Were the action of the bile other than soothing, its normal presence in the stomach would not so uniformly coincide with the resting period of the organ.

"Even in gastric disturbance with nausea and vomiting the pylorus relaxes and bile pours into the stomach until the entire organ is coated and bile is ejected from the mouth. From the nauseous taste of the vomit it is a common concept that the bile has disturbed the stomach, but it is much more logical to believe that the regurgitation of bile is a protective mechanism of nature, serving to neutralize the offending gastric contents and to soothe and quiet the irritated walls of the stomach. In the duodenum and jejunum the protective influence of bile and pancreatic juice is shown by many observations. Ulcers of upper intestine are exceedingly rare, except in the first portion of the duodenum, where there is the least opportunity for the neutralization of the chyme by the bile and pancreatic juice. If by operation we reduce or eliminate the protective influence of the bile and pancreatic juice against the chyme in the duodenum and jejunum, ulceration becomes common".

Babcock continues: "Exclusive of non-absorbable suture ulceration, gastrojejunostomy is followed by ulcer of the jejunum in about 2 per cent of the cases. When the bile and pancreatic juice are diverted from a segment of the jejunum, as by the Roux gastro-enterostomy, the percentage of secondary ulcers greatly increases. In six out of seven dogs in which Exalto anastomosed the jejunum with the stomach after diverting the duodenal fluids in the colon, jejunal ulcers occurred. It is said that, unlike gastrojejunostomy, gastroduodenostomy is not followed by jejunal ulcer. If the bile and pancreatic ducts are transplanted from the duodenum to the upper jejunum by operation, ulcers of the duodenum frequently follow. Therefore, whenever chyme from the stomach enters the upper intestinal tract without sufficient admixture with bile and pancreatic juices, ulcers are prone to develop, and there can be little question that the latter fluids normally protect the duodenum and jejunum from ulceration. As to the exact elements that cause the ulceration, free hydrochloric acid, acid pepsin, toxins in solutions, bacteria, or other agents, and the precise protective elements in the duodenal fluids, alkalis, mucus, nucleo-albumin, or other substance, we will not brook unproductive dispute by attempting to name. As surgeons, we think it unnecessary to enter the controversy as to whether or not peptic ulcers depend chiefly upon the hydrochloric acid content of the gastric juice."

"With such complex fluids it is unnecessary to assume that a single element is entirely responsible for any particular activity. Bread is equally nourishing to the man who does not fully understand its composition, and bile may serve the surgeon not versed in its chemistry."

"If it be true that it is chiefly the protective film of bile covering the mucosa that permits the average ulcer to heal, then we would suggest that the simple anastomosis of the gall-bladder into the area of ulceration or into the area left after excision of the ulcer (cholecysto-ulcerostomy) be substituted for the more formidable and difficult gastro-enterostomy."

According to Babcock, "the advantage of such an operation lies not merely in the greater accessibility of structures to be anastomosed, but in the fact that the bile is directly delivered to the part where it is most needed, while the dangers of a secondary jejunal ulcer or the other complications of a gastro-enterostomy are avoided. The entrance of the bile into the stomach does not necessarily produce symptoms. Patients who have had cholecysto-gastrostomy performed seem

to be unconscious of the increased quantity of bile in the stomach. While the bile entering the stomach after a cholecysto-gastrostomy reduces the total acidity, it does not abolish gastric digestion by completely neutralizing the chyme. Although acid chyme is completely neutralized in the duodenum, Dunn's experiments show that the entrance of all the bile and pancreatic juice into the stomach will not completely alkalinize the gastric contents. Of course, the surgeon aims to protect only the irritated areas of mucosa, not to completely alter the chemistry of gastric digestion. Fortunately the normal tendency for the gastric contents to remain in well-defined strata and for fluids entering from new openings to diffuse along mucous surfaces is of aid to the surgeon."

In a paper under the title of "Cholecysto-gastrostomy and Cholecysto-duodenostomy," F. G. Du Bose, of Alabama, suggests the operation as a treatment for perforated gastric or duodenal ulcer and for persistent pylorospasm due to hyperacidity, but makes no mention of having done it. He says, however, "probably experience will prove that cholecysto-gastrostomy is as useful in gastric ulcer as gastro-enterostomy."

Whilst still ignorant of any writings on this subject I embarked on my adventure. In May, 1925, I did my first cholecysto-gastrostomy for *inaccessible* gastric ulcer. The case was a failure; the patient succumbed on the tenth day from a suppurative parotitis with thrombosis of the internal jugular vein; the site of operation was perfect and there had been no sickness. Since this time I have done, in all, 64 cases for high or difficult gastric ulcer, 10 for recurrent, intractable duodenal ulcer, and 5 for a hyperchlorhydria and pyloric spasm with typical duodenal symptoms. In almost all cases the appendix as the potential course of the trouble was removed. The operations presented very little technical difficulty; some were very ill, and a second case died (from uræmia). The last operation was in 1936.

In these days it is not easy to obtain replies to postal inquiries, but I have just received 41 from infirmary and 5 from private cases; 3 cases are thus known to have died from conditions not connected with the gastric or duodenal disease and 1 case from gastric carcinoma in the case of a very big gastric ulcer which was probably already malignant.

The majority of the patients speak with much gratitude, but 40 per cent of those who replied had a repetition of symptoms from 1½ to 2 years after operation—in 6 of these cases the abdomen was re-opened, and in all the anastomosis was found to be closed. Reconstitution of the anastomosis again relieved the symptoms in the 6 cases referred to and in 7 others who did not reply but who had renewed indigestion. Rehfuss tests before operation showed no increase of bile in the stomach and no diminution in acidity.

In no case did further operation reveal an anastomotic ulcer or any damage to the liver; in 4 a gastric ulcer was definitely still present though smaller; in 5 of the other cases where recurrence of symptoms occurred, and where X-ray examination was made, a gastric ulcer was still present but probably smaller; in 13 cases re-examined by X-ray and symptomatically well, the gastric ulcer was found to be healed.

The symptomatic relief afforded in all cases may be very misleading (it is to be remembered that the appendix was usually removed), but it certainly was very striking. It is unfortunate it was not possible to assess the degree of pyloric spasm, if any, present after operation so exactly as to give any figures; my impression is that it was definitely lessened.

And so the adventure ended in a comparative failure—the results pleased me as well as post-gastro-enterostomy had done, but I had to recognize that in 1½ to 2 years my anastomosis might close in probably 50 per cent of the cases.

Then came partial gastrectomy for gastric and sometimes for duodenal ulcer; this satisfied me almost completely in that a gastric ulcer as a potential site of carcinoma was removed together with much of the 'acid-bearing' portion of the stomach.

It may be said, "Why did you not, obsessed as you were with the value of bile in the stomach, administer bile-salts by mouth?" I have frequently done so since with little result, but in those days bile-salts were not easy to obtain and are still different in many way from natural bile. I wanted human bile to be given absolutely *automatically* at definite times, I wished the treatment to be intensive and without a single omission, and I wanted to see the ulcer, to feel it, and gauge the possibility of malignant disease; I also desired to remove the appendix.

I knew that bile-salts had been, and are now, given for the treatment of peptic ulcer, especially in America, where good results are claimed.

And so what is the end of it all? Just an adventure in surgical physiology; perhaps a little more knowledge of the reality and effect of biliary regurgitation.

I like to think the word "research" may one day be applicable to something done outside the test tube and laboratory, to work carried out on humanity rather than on animals. Surgeons *do* carry out true research in the course of their daily work, and I believe, as Moynihan contended, that in the doing of it they can best promote the future of surgery; some day indeed it may be recognized that experimental surgery on animals has already passed all reasonable limits, and in any event *has* not and probably *cannot* hope to compete with observation and invention as carried out on man, and practised as it is with affectionate and sympathetic understanding.

I would like to acknowledge my deep debt to the President and Council of this College for giving me the opportunity in this and in the Moynihan Lecture of putting forward views which I fully recognize are controversial. I have

done so in no spirit of vanity but in the hope that the recitation of the two subjects which have most interested me in a long and busy surgical life may stimulate those who follow.

> Not heaven itself over the past hath power,
> But what has been, has been, and I have had my hour.

I desire especially to acknowledge the great assistance given to me in the preparation of this Lecture by Professor Hemingway, of the Department of Physiology in the University of Leeds, who is responsible for the account of the modern conception of biliary regurgitation.

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THE ROLE OF CHEMOTHERAPY IN THE TREATMENT OF HÆMATOGENOUS OSTEOMYELITIS

BY K. C. McKEOWN

THE extent of surgical intervention desirable in cases of acute hæmatogenous osteomyelitis has been the subject of much debate and diversity of opinion. Formerly the radical procedure of extensive bone guttering was in favour, while at present the surgical pendulum has swung in favour of bone drilling, or even of simple incision of the periosteum over the affected metaphysis. These latter procedures have not, however, proved uniformly successful. It is a common experience to find that the more conservative measures prove insufficient, and that more drastic intervention has to be undertaken to stem the tide of spreading bone infection and increasing toxæmia.

The spectacular success of chemotherapy in the treatment of pyogenic infections has prompted its use in cases of osteomyelitis. In general, it may be said that the use of chemotherapy in various infective lesions has limited the extent of surgical intervention. It is, therefore, not unreasonable to assume that the use of chemotherapy may limit the extent of surgical intervention in cases of acute osteomyelitis.

With this as a working hypothesis, an investigation into the use of sulphathiazole in the treatment of osteomyelitis has been carried out; an interim report has already appeared (McKeown, 1942). A series of 26 cases has been treated with sulphathiazole combined with various types of surgical intervention. With a view to assessing the results obtained, a comparative review of 74 cases treated by the same surgical procedures, but without the use of chemotherapy, has been made.

The cases to be recorded are, for convenience and clarity, divided into four groups, though it must be admitted that this grouping is not entirely satisfactory.

In Group 1 sulphathiazole was given in doses of 1 g. per 20 lb. body-weight per day. Administration was begun at the onset of the disease and continued for eight days. An interval of three weeks intervened, and then a repeat course of

similar dosage and duration was given. This system of administration was instituted to prevent the ill effects of prolonged absorption of the drug. The surgical treatment in these cases consisted, in the main, of making multiple drill holes in the metaphysis. Operation was carried out between the second and sixth day of the disease, and the closed plaster technique was adopted.

Cases in Group 2 were given sulphathiazole in adequate doses, but surgical intervention was minimal. In the first case in this group no operation in the acute stage of the disease was carried out, while in the other cases the periosteum only was incised.

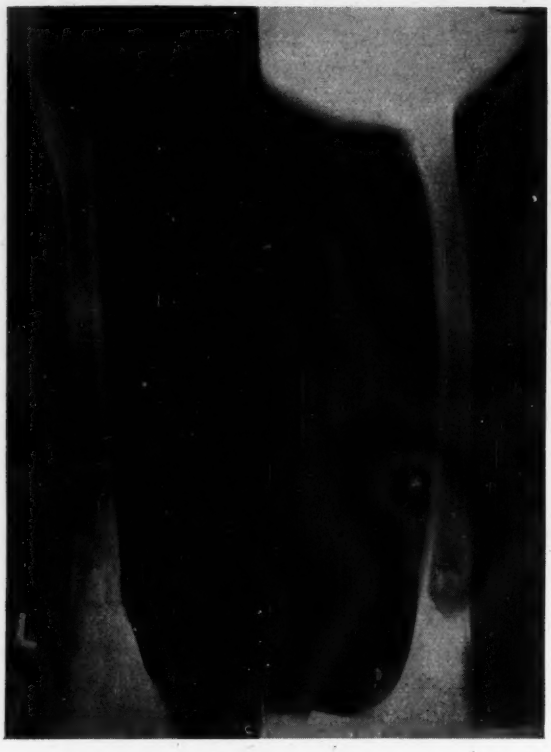

FIG. 10.—*Case* 1. Radiograph at three months, showing osteomyelitis of the lower end of femur. Only a small flake of the originally drilled cortex has sequestrated and involucrum formation is minimal.

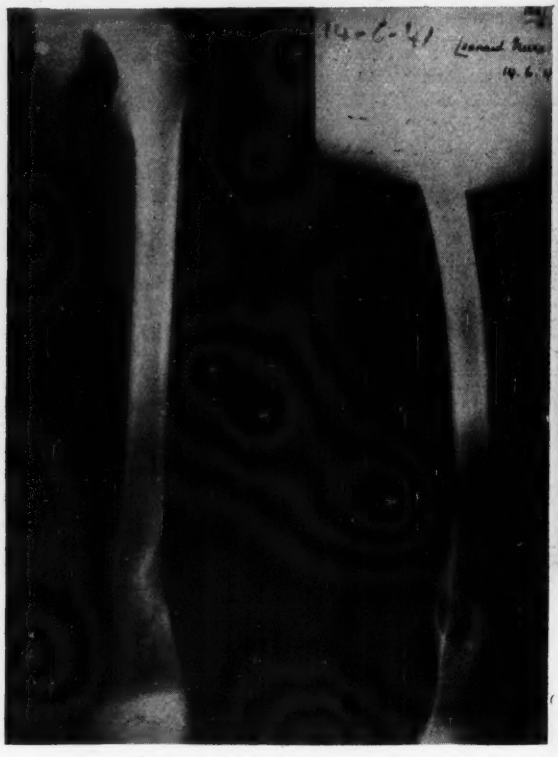

FIG. 11.—Same case at six months, showing that healing was complete. The bone changes are confined to a very small area.

In Group 3 sulphathiazole was given in two courses as in the first group, but the operative treatment consisted of incision of the periosteum and extensive bone guttering.

Group 4 consisted of cases in which bone drilling was carried out, but sulphathiazole was either given in very small doses or its administration was not started until a considerable time after the onset of the disease.

CASE RECORDS

Group 1. Sulphathiazole and Bone Drilling.— *Case* 1.—L. E., a boy of 10 suffering from osteomyelitis of femur, of moderate severity. Sulphathiazole was given as indicated above and the bone drilled on the second day. Pus examination, *Staph. aureus*. Blood-sulphathiazole concentration 7 mg. per cent. At three months X-ray showed a small sequestrum (*Fig.* 10). This was removed. In six months the sinus was healed and X-ray showed minimal bone change (*Fig.* 11). Functional result excellent.

Case 2.—V. H., aged 1 year, suffering from osteomyelitis of tibia. Sulphathiazole was given and the bone drilled. Pus examination, *Staph. aureus*. Blood-sulphathiazole 2 mg. per cent. In three months the wound was healed and radiography showed a minimal degree of bone change. Sequestration did not occur.

Case 3.—D. H., girl, aged 8, developed osteomyelitis of femur, following injury. The femur was trephined and sulphathiazole given as above. Blood-sulphathiazole, 3·7 mg. per cent. Pus culture, *Staph. aureus*. Radiography at one month showed that the osteomyelitic changes were mild and localized (*Fig.* 12). Small flakes of sequestrum were removed from the sinus, which healed in four months. Radiography on discharge showed only a mild degree of bone change (*Fig.* 13).

Case 4.—P. M., boy of 9 suffering from osteomyelitis of the humerus. Sulphathiazole was given and the bone drilled on sixth day of illness. Healing complete in four months and X rays showed no bone change.

Case 5.—A. D., aged 11. Osteomyelitis of femur. Sulphathiazole given in two courses and bone drilled

on sixth day. Pus culture, *Staph. aureus*. Blood-culture sterile. White-cell count, 21,000. After two months a small sequestrum was removed and the sinus healed in four months. Functional result excellent.

Case 6.—E. S., girl of 8, with severe osteomyelitis of femur. Sulphathiazole and sulphapyridine were given in separate courses. The femoral metaphysis was drilled on the sixth day. Blood-sulphathiazole, 3·7 mg. per cent. Pus culture, *Staph. aureus*. White-cell count, 19,000. Sequestration of only small flakes of bone occurred; these were removed and the sinus healed in seven months.

Case 7.—S. D., aged 4. Osteomyelitis of humerus with metastatic abscesses in ankle and knee. Bone was drilled and the abscesses incised. Sulphathiazole given as indicated above. In three months all sinuses had healed and X-ray examination showed minimal bone change.

Case 8.—G. M., boy of 9 with mild osteomyelitis of tibia. Treatment was the same as in above cases. Blood-sulphathiazole, 3·3 mg. per cent. In three months healing was complete and radiographs showed no bone change.

Case 9.—R. K., boy of 7, had moderately severe osteomyelitis of femur. Bone was drilled and chemotherapy given (uleron and sulphathiazole). X-ray examination at two months showed localized osteomyelitis but no gross sequestration. Duration of treatment was five months and the functional result very good.

Case 10.—J. H., girl of 10, developed osteomyelitis of femur following injury. The femoral metaphysis was drilled and five days later sulphathiazole was given. Sequestrectomy was performed at six months, and a pedicle muscle-graft inserted into the bone cavity. Healing was complete in ten months and the bone changes remained localized.

Case 11.—H. T., aged 8. Osteomyelitis of tibia of moderate severity. Bone drilling was carried out and sulphathiazole given. Sequestrectomy was performed at three months and healing was complete at eight months.

FIG. 12.—*Case* 3. Radiograph at one month, showing osteomyelitic changes confined to a small area at the lower end of the femur.

FIG. 13.—Same case at four months, showing that the lesion at the lower end of the femur has healed. No extensive periosteal new-bone formation has occurred, and the bone architecture has not been grossly altered.

Case 12.—S. W., girl of 11, suffering from exceedingly severe osteomyelitis of tibia with multiple pyæmic abscesses, and a suppurative arthritis of the knee-joint. The upper end of the tibia was drilled and pus aspirated from the knee-joint. The metastatic abscesses were also incised. Sulphathiazole was given by mouth and intravenously in repeated courses. Pus culture, *Staph. aureus*. Blood-culture positive. After two months of intense toxæmia the patient's condition improved. Small sequestræ were removed and at twelve months cavities at upper and lower end of tibia were saucerized. Radiographs at two months showed discrete osteomyelitic foci at upper and lower end of tibia (*Fig.* 14). Subsequent radiographs showed that the two lesions had remained discrete, gross sequestration had not taken place, and only a moderate amount of involucrum formation was present.

Case 13.—J. B., girl of 11, developed osteomyelitis of neck of femur following injury. Sulphathiazole

was given. The upper end of the shaft was drilled, but two weeks later the femoral neck had to be exposed. Sequestræ were removed from the sinus, which healed in nine months. The femoral head and shaft did not become involved.

Case 14.—D. W., aged 10. Osteomyelitis of os calcis with a metastatic abscess of clavicle. Bone drilling was carried out and sulphathiazole given as above indicated. Blood-sulphathiazole, 3·6 mg. per cent. X-ray examination showed inflammatory changes in posterior third of the bone (*Fig.* 15). Healing was complete in three months and sequestration did not take place.

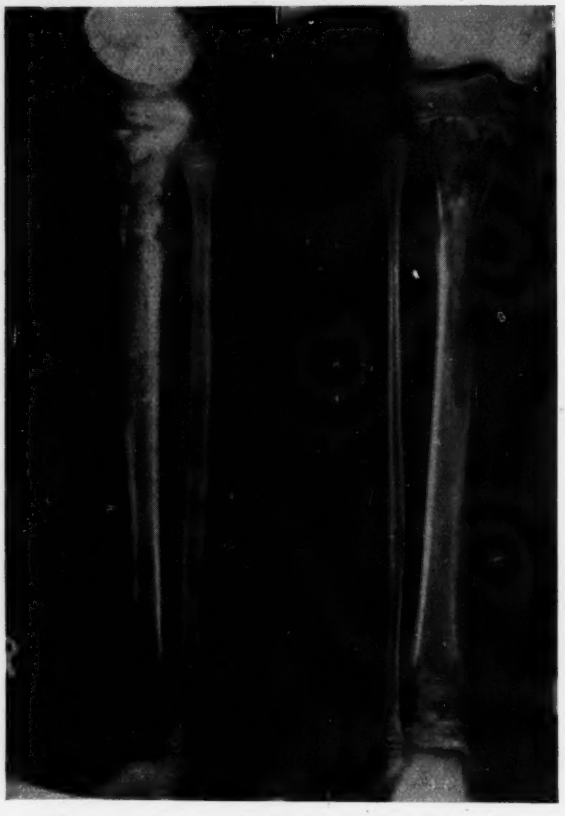

FIG. 14.—*Case* 12. Radiograph at two months, showing two separate lesions in upper and lower tibial metaphyses.

Case 15.—R. G. had a clinical history identical with *Case* 14, but sulphathiazole was used locally in the wound and none given by mouth. Bone destruction in this case was more severe (*Fig.* 16), sequestrectomy was required, and the disease lasted nine months.

Case 16.—J. J., aged 2. Osteomyelitis of os calcis. Treatment as in *Case* 14, except that the inner and outer aspects of the os calcis were drilled, on the first and third day respectively. Pus culture, *Staph. aureus*. White-cell count, 38,000. Healing was complete in five months, with minimal radiographic bone change.

Case 17.—R. C., boy of 4. Osteomyelitis of os calcis. Treatment as in *Case* 14. Healing was complete in five months, the functional result good, and radiographic bone change minimal.

Group 2. Sulphathiazole and Minimal Operative Interference.—

Case 18.—J. H., boy of 10, with staphylococcal osteomyelitis of tibia. Sulphathiazole was given in large doses and plaster applied, but no operation was performed in the acute stage. Blood-sulphathiazole, 4.2 mg. per cent. After two months of critical illness the leg was still œdematous and painful, and multiple discharging sinuses were present. Operation became necessary on account of increasing toxæmia. The lower end of tibia was guttered and dead bone removed. The degree of bone destruction was severe and the patient was still under treatment after ten months.

FIG. 15.—*Case* 14. Radiograph at one month. Osteomyelitic changes of mild degree are present in the posterior third of the os calcis.

FIG. 16.—*Case* 15. Radiograph at one month. The osteomyelitic changes in the os calcis are much more severe than in *Fig.* 15, and sequestration has taken place.

Case 19.—R. T., boy of 8. Osteomyelitis of tibia. Sulphathiazole was given as for cases in Group 1; operation, however, consisted of incision of periosteum only. Extensive bone necrosis occurred (*Fig.* 17), necessitating repeated sequestrectomies. After twelve months the sinus healed but X rays showed extensive bone sclerosis (*Fig.* 18).

Case 20.—G. H., aged 12. Osteomyelitis of tibia, treated in same way as *Case* 19. Blood-sulphathiazole, 3 mg. per cent. After six months the limb was still painful and swollen and multiple discharging sinuses were present. Radiography showed extensive bone destruction of entire tibial shaft. The ankle-joint was stiff and movements of the knee markedly limited.

Group 3. Sulphathiazole and Bone Guttering.—

Case 21.—D. Mc.D., aged 9, developed osteomyelitis of femur following a strain. Sulphathiazole given as for cases in Group 1. Blood-sulphathiazole, 3·5 mg. per cent. The lower end of the bone was guttered on the sixth day. Sequestration took place

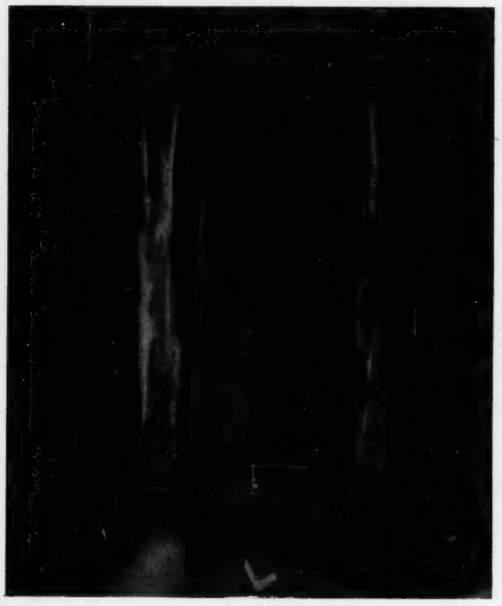

FIG. 17.—*Case* 19. Radiograph showing extensive bone necrosis of tibia with involucrum formation.

FIG. 18.—Same case. Radiograph showing that the tibial lesion has healed with extensive bone sclerosis.

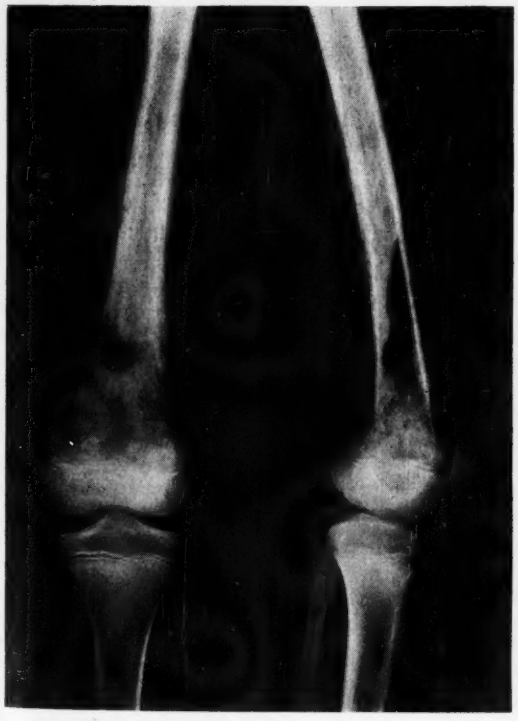

FIG. 19.—*Case* 21. Radiograph at one month. Osteomyelitic changes are present in the lower end of the femur, and the guttered cortex can be seen clearly. Sub-periosteal new-bone formation extends to the middle of the shaft.

FIG. 20.—Radiograph of same case at three months, showing a large sequestrum and much new-bone formation. Compare with *Figs.* 10–13.

and radiographically the degree of bone change was severe (*Figs.* 19, 20). The patient is still under treatment.

Case 22.—A. L., aged 10, developed osteomyelitis of tibia following injury. Treatment was similar to *Case* 21. Extensive necrosis of tibia occurred with marked involucrum formation. Duration of treatment, fourteen months.

Group 4.—Sulphathiazole given at a Late Stage in the Disease or in Very Small Doses, and Combined with Bone Drilling.

Case 23.—I. P., girl of 14, suffering from osteomyelitis of tibia, with effusion into the knee-joint. The bone was drilled on the second day but sulphathiazole was not given until the twelfth day. Though the inflammatory process did not spread to the tibial shaft, the changes at the upper end of the bone were moderately severe and the knee-joint was involved. Duration of treatment, ten months.

Case 24.—D. M., boy of 8, with osteomyelitis of tibia. The bone was drilled but the dose of sulphathiazole given was very minute (0·5 g. per day). Sequestration of the upper end of the shaft occurred, the epiphysis became involved, and the degree of bone change was very severe. After thirteen months the sinuses were still discharging and the knee was stiff.

Case 25.—R. C., boy of 10, developed osteomyelitis of femur following injury. The lower end of femur was drilled but sulphathiazole was not given until six weeks after the onset of the disease. Extensive destruction of bone took place and treatment lasted fourteen months.

Case 26.—A. T., aged 11. Osteomyelitis of tibia. Bone drilled on second day. No sulphathiazole given until ten weeks after the onset of the disease. X rays showed very severe bone destruction (*Fig.* 21). After six months the leg was still swollen and multiple profusely discharging sinuses were present.

With a view to epitomizing these case records and emphasizing certain points to be discussed later, *Table I* has been compiled, showing the type and time of operation, and the dose and time of administration of sulphathiazole. The duration of the disease and the end-results also are charted. In assessing the end-results, the points considered were the duration of the disease until the sinuses had soundly healed, the degree of bone change on X-ray examination, and the functional result.

REVIEW OF THE CASE HISTORIES

In reviewing these cases, the first and most obvious comment is that the administration of sulphathiazole in the early stages of acute osteomyelitis, when combined with bone drilling, appears to confine the destructive bone changes to a relatively small area and to minimize their severity. The duration of the disease also is remarkably short.

Secondly, when sulphathiazole is given at a late stage in the disease or in small doses, as in Group 4, the favourable features observed in Group 1 are no longer attained, though the surgical intervention was identical.

Thirdly, early administration of adequate doses of sulphathiazole is not, in itself, sufficient to limit the severity of bone infection unless combined with surgical intervention (e.g., *Case* 18). A review of cases in Groups 2 and 3 appears to indicate that simple incision of the periosteum does not provide sufficient drainage; while the procedure of bone guttering appears to be unnecessarily extensive and even harmful.

FIG. 21.—*Case* 26. Radiograph at two months, showing extensive bone destruction and involucrum formation.

Arising out of the above general considerations, five points have been selected for further discussion, namely: (1) The role of chemotherapy in the early and late stages of the disease. (2) The optimum dose of sulphathiazole. (3) The type of operative interference necessary. (4) The degree of bone change on radiographic examination. (5) The duration of the disease as compared with other series of cases.

1. The Role of Chemotherapy in the Early and Late Stages of the Disease.—It has already been emphasized that to be effective, the drug must be given in the early stages of the disease. Early administration secures the bacteriostatic effect of the sulphonamide before the infection becomes firmly established and thereby the local and general defensive mechanisms have time to become effective. By this means the severity of the bone lesion is limited. In addition,

early administration ensures that the drug is able to reach the site of infection before pressure and thrombosis interfere with the vascular supply of the affected metaphysis.

As a corollary of the above considerations it may be inferred that chemotherapy will be less effective in the chronic phase of osteomyelitis where the bone is sclerosed and avascular.

With a view to confirming this corollary, a series of 15 cases of chronic osteomyelitis were given adequate doses of sulphathiazole for periods varying up to two weeks. Four of these cases showed diminished discharge from the sinuses while sulphathiazole was being given, but after the drug was stopped, the discharge became as profuse as previously. In the other 11 cases, no change whatever was noticed in the general or local conditions of the patients under observation.

These results confirm the deduction that sulphathiazole is ineffective in the chronic phase of osteomyelitis.

Table I.—Summary of Results of Chemotherapy

Case	Site	Chemotherapy		Surgical Treatment		Result		
		Dose	Time	Type	Time	Duration	Bone Change	Function
Group 1.—						mth.		
1	Femur	Adequate	2nd day	Drilling	2nd day	6	Mild	Excellent
2	Tibia	Adequate	2nd day	Drilling	2nd day	3	Minimal	Excellent
3	Femur	Adequate	2nd day	Trephine	2nd day	5	Mild	Good
4	Humerus	Adequate	2nd day	Drilling	6th day	4	None	Excellent
5	Femur	Adequate	3rd day	Drilling	3rd day	4	Mild	Excellent
6	Femur	Adequate	2nd day	Drilling	6th day	7	Mild	Very good
7	Humerus	Adequate	1st day	Drilling	1st day	3	Minimal	Excellent
8	Tibia	Adequate	1st day	Drilling	5th day	3	None	Excellent
9	Femur	Small	4th day	Drilling	4th day	5	Mild	Very good
10	Femur	Adequate	1st day	Drilling	5th day	10	Mild	Very good
11	Tibia	Adequate	5th day	Drilling	5th day	8	Mild	Good
12	Tibia and Multiple foci	Adequate	1st day	Drilling	3rd day	17	Moderate	Fairly good
13	Neck of Femur	Adequate	2nd day	Drilling and guttering	3rd day & 14th day	10	Localized, but severe	Fairly good
14	Os calcis	Adequate	2nd day	Drilling	2nd day	3	Minimal	Excellent
15	Os calcis	Local	2nd day	Drilling	2nd day	9	Moderate	Good
16	Os calcis	Adequate	2nd day	Drilling	1st day	5	Minimal	Good
17	Os calcis	Adequate	3rd day	Drilling	3rd day 6th day	5	Mild	Good
Group 2.—								
18	Tibia	Adequate	2nd day	No operation	—	10	Severe	Fair*
19	Tibia	Adequate	2nd day	Incision of periosteum	2nd day	12	Severe	Fair
20	Tibia	Adequate	4th week	Incision of periosteum	3rd day	6	Severe	Fair*
Group 3.—								
21	Femur	Adequate	6th day	Guttering	6th day	7	Severe	Fair*
22	Tibia	Adequate	6th day	Guttering	6th day	14	Very severe	Fair
Group 4.—								
23	Tibia	Adequate	2nd week	Drilling	2nd day	10	Moderate	Fair
24	Tibia	Very small	1st week	Drilling	7th day	13	Very severe	Poor*
25	Femur	Adequate	4th week	Drilling	2nd day	13	Very severe	Fair
26	Tibia	Adequate	10th week	Drilling	2nd day	6	Very severe	Poor*

* Cases still under treatment.

2. The Optimum Dose of Sulphathiazole.—The futility of inadequate dosage has already been demonstrated (e.g., *Case* 24). The ultimate criterion of adequate dosage must be the concentration of the drug obtained in the blood-stream. Experimental studies, carried out mainly in America, suggest that to be effective a blood concentration of 2·5 mg. per cent as a minimum should be obtained.

It therefore became necessary to investigate the factors which control the blood concentration of the drug. A series of experimental studies was carried out, in each of which three cases were under observation.

The first investigation was to find out the relationship between the fluid intake and the blood concentration of the drug. A constant dose of 0·8 g. per 20 lb. body-weight per day was given to each of the three cases for a period of nine days. During the first three days the fluid intake was limited to one pint in the twenty-four hours. During the third to the sixth day the fluid intake was two pints, and from the sixth to the ninth day the intake was increased again, to four pints.

Fig. 22 shows a graphic representation of the findings. Increase of the fluid intake from one to two pints did not reduce the blood concentration of sulphathiazole. In fact, contrary to what might be expected, two of the cases showed slight increases in the blood concentration. When, however, the fluid intake was increased to four

pints per day, all cases showed appreciable fall in the blood concentration.

It was found that restriction of the fluid intake to one pint was particularly distressing to the patient, while with two pints they were comparatively comfortable. It may be concluded, therefore, that a fluid intake of two pints per day does not reduce the blood-sulphathiazole and yet provides adequate fluid intake for the comfort of the patient. Increase of the fluid intake above this level, however, causes an appreciable fall in the blood-sulphathiazole concentration.

A feature of particular interest was the examination of the urine throughout these investigations. It will be seen that when the blood concentrations of the drug reach 6 mg. per cent or over, albuminuria occurred. A dosage of 1 g. per 20 lb. body-weight per day produces a blood concentration just below this level. It may be concluded, therefore, that this dosage is the optimal one.

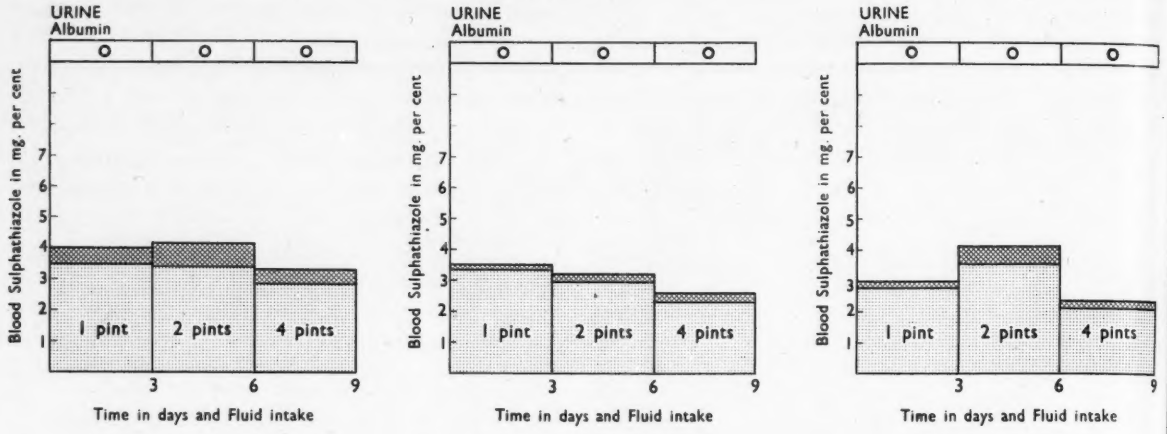

FIG. 22.—Graph showing the relationship between fluid intake and the blood sulphathiazole concentration. Dose, 0·8 g. per 20 lb. body-weight per day.

Free sulphathiazole in the blood represented by ▭ Acetyl compound in the blood represented by ▨

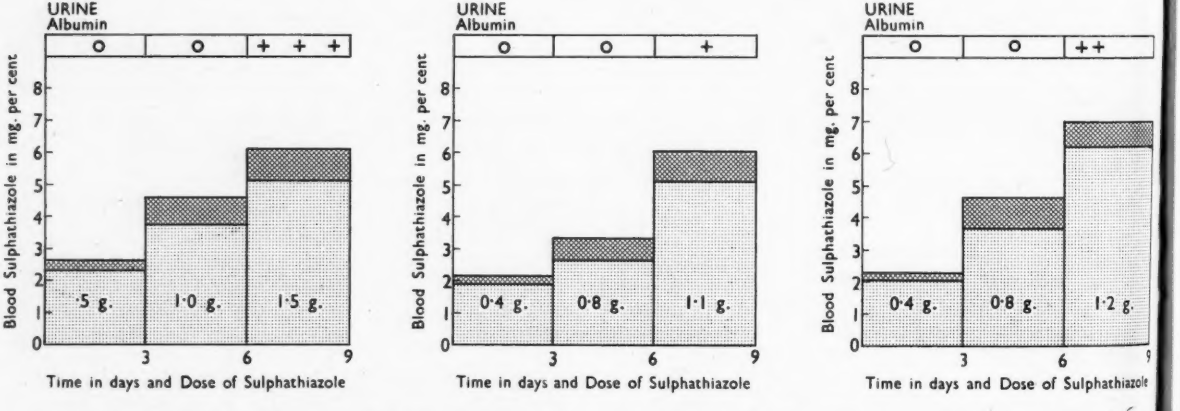

FIG. 23.—Graph showing the relationship between the dose of sulphathiazole and the blood concentration of the drug. Dose of sulphathiazole indicated in grammes per 20 lb. body-weight. Fluid intake, 2 pints per day.

Free sulphathiazole in the blood represented by ▭ Acetyl compound in the blood represented by ▨

The second investigation was to ascertain the relationship between the dose of sulphathiazole and the concentration of the drug in the blood, the fluid intake being constant.

Fig. 23 shows the result of this investigation. It is seen that increase in the dosage of the drug results in a corresponding and approximately proportional increase in the blood concentration.

The occurrence of albuminuria in cases under treatment with sulphathiazole has been attributed to the trauma of undissolved crystals in the urine (Climenko, Barlow, and Wright, 1941). It has also been suggested that the maintenance of alkalinity of the urine will increase the solubility of the crystals, consequently reducing the incidence of albuminuria (Schwartz, Fillipin, Reinhold, and Domm, 1941).

With a view to confirming this thesis, large doses of sulphathiazole were given to three

patients, the actual dose being estimated as 1·5 g. per 20 lb. body-weight per day. The reaction of the urine was maintained strongly alkaline by repeated doses of sodium bicarbonate, after which the reaction was made acid by giving acid sodium phosphate. *Fig.* 24 shows the results obtained. It is seen that alkalinity of the urine does not prevent albuminuria, and that the presence of crystals in the urine has no constant relationship to its incidence. Indeed, the incidence of albuminuria was less with an acid urinary reaction than with an alkaline reaction.

A point of considerable interest, however, was that in certain specimens of the urine, urobilin and porphyrins were present.* This finding suggests that the primary damage caused by the drug may be hepatic rather than renal.

Subsequent investigations showed that if nicotinic acid were given to patients under treatment with sulphathiazole, urobilin and porphyrins could no longer be detected in the urine. In addition, larger doses of sulphathiazole could be given without causing albuminuria. For example, two cases under observation were given doses of sulphathiazole estimated at 1·5 g. per 20 lb. body-weight per day, together with nicotinic acid (100 mg.). The blood-sulphathiazole concentrations were 11·9 and 9·8 mg. per cent respectively, but contrary to what might have been expected with such large dosage, albuminuria did not occur.

It is suggested, therefore, that the administration of nicotinic acid may allow of increase of sulphathiazole dosage above the optimal amount already mentioned, without causing hepatic or renal damage.

3. The Type of Operative Interference Required.—The possibility that the use of chemotherapy may limit the extent of surgical intervention required in acute osteomyelitis has already been discussed in the introduction of this paper. It merely remains to be stated that a review of the above cases suggests that bone drilling is the operative measure of choice when combined with early administration of adequate doses of sulphathiazole. It need hardly be reiterated that before the advent of sulphathiazole, bone drilling by no means always provided adequate drainage, nor did this procedure necessarily prevent spreading bone infection.

4. The Degree of Bone Change.—A striking feature of the radiographs of cases in Group 1 is the minimal degree of bone change. Out of 17 cases, 2 showed no radiographic changes, though the diagnosis was not in doubt. This is a finding which has been mentioned in a recent paper by Melton. Of the remaining 15 cases in this group, 7 did not show sequestration though osteomyelitic changes were present, while the remaining 8 showed sequestration of small pieces of bone, some of which could be removed without formal operation.

It is believed that this absence of sequestration, or sequestration of minimal extent, is a point of particular interest and significance.

In reviewing the pathology of osteomyelitis, it is found that when sequestration begins to take place there ensue a definite series of changes in the affected bone. Periosteal new-bone formation takes place, and forms a coral-like mass of bone enclosing the central area of sequestration. This involucrum formation may be regarded as a normal reaction, invoked by the presence of dead or dying bone. Its occurrence may not, however, be an entirely beneficent reaction. Assuming that the dead bone is removed, the patient's troubles are by no means over, for though the involucrum becomes dense and sclerotic, the residual infection causes the sinus to continue to discharge. A vicious cycle is then established of chronic infection causing sclerosis of the bone, which in turn is unable adequately to combat the infection because of its lack of vascularity. It is a commonplace that the sinuses overlying the

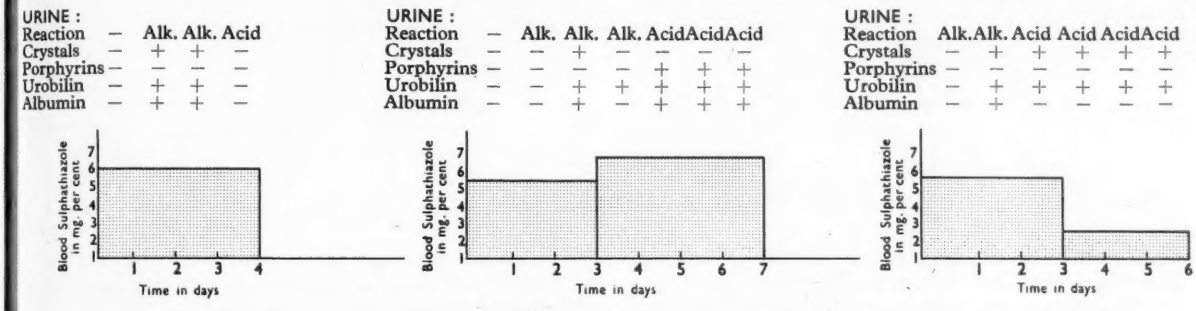
URINE :
Reaction – Alk. Alk. Acid
Crystals – + + –
Porphyrins – – – –
Urobilin – + + –
Albumin – + + –
URINE :
Reaction – Alk. Alk. Alk. Acid Acid Acid
Crystals – – + – – – –
Porphyrins – – – – + + +
Urobilin – – + + + + +
Albumin – – + – + + +
URINE :
Reaction Alk. Alk. Acid Acid Acid Acid
Crystals – + + + + +
Porphyrins – – – – – –
Urobilin – + + + + +
Albumin – + – – – –
Blood Sulphathiazole in mg. per cent
Time in days

FIG. 24.—Graph showing the incidence of albuminuria and the presence of crystals, porphyrins, and urobilin in the urine. Dose of sulphathiazole was constant in each investigation.
Free and combined sulphathiazole in the blood represented by ▭

* Acidification of amyl alcoholic extracts from specimens of urine produced a bright red colour which when viewed through the spectroscope caused a general absorption at the violet-green-yellow end of the spectrum. The red colour faded, and a faint absorption band resembling acid porphyrin was observed with the spectroscope.

sclerotic bone in chronic osteomyelitis show little tendency to heal, and if that happy event should occur, the tendency to break down again is particularly marked. It is these latter features that give to osteomyelitis its prolonged incapacitating effect.

It is suggested that early and adequate administration of sulphathiazole, combined with bone drilling, limits the extent of bone necrosis in the early stages of the disease and thereby prevents the establishment of a series of reactive changes which lead to chronic osteomyelitis.

The above considerations lead naturally to the final point of discussion, namely, the duration of the disease.

5. The Duration of the Disease.—It has already been noted in the general comment that the duration of osteomyelitis appears to be considerably shortened by the use of sulphathiazole. A comparative study of the duration of the disease has been made by reviewing a series of 74 cases treated at Queen Mary's Hospital, Carshalton, before the advent of sulphathiazole. The results of this review are tabulated in *Table II*. Unfortunately, due to insufficient data, certain parts of the table have been left incomplete. It is obvious, however, that administration of sulphathiazole considerably reduced the duration of the disease, irrespective of the type of operative interference.

Sulphathiazole combined with bone drilling reduced the duration of the disease by 60 per cent. An explanation of this reduction in the duration of treatment has been offered in the above section.

Table II.—Showing the Duration of Osteomyelitis when Treated by Various Types of Operation, with and without Chemotherapy

Site	No Chemotherapy				Chemotherapy			
	Incision	Drilling	Guttering	Average	Incision	Drilling	Guttering	Average
	mth.	mth.	mth.		mth.	mth.	mth.	
Tibia	15	22	33	23	11	8½	14	11
Femur	22	23	23	23	—	6½	—	6½
Humerus	—	—	—	25	—	3½	—	3½
Os calcis	25	—	—	26	—	6	—	6
Neck of Femur	—	—	—	37	—	—	—	11

SUMMARY

The use of sulphathiazole in the treatment of acute hæmatogenous osteomyelitis is reviewed. A review of 100 cases has been carried out; the 26 cases treated with sulphathiazole have been recorded in detail.

The importance of early administration and carefully estimated doses of the drug is emphasized. Certain factors relating to the concentration of the drug in the blood are discussed, and the dangers of kidney or liver damage resulting from over-dosage have been mentioned.

An explanation of the role played by sulphathiazole has been offered.

Bone drilling is regarded as the operative measure of choice.

Finally, I wish to express my sincere gratitude to the late Mr. Lambrinudi for his constant interest and encouragement while investigating this series of cases, and to Drs. Mulvanny and Reeve for their assistance in this investigation.

I wish also to thank Dr. Allen Daley for permission to use the clinical material available at Queen Mary's Hospital, Carshalton.

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INTUSSUSCEPTION OF THE APPENDIX

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Intussusception of the appendix is rare, only about 100 cases having been reported since McKidd published an account of the first case in 1858. In the present paper I report 7 new cases, and review 75 cases reported in journals to which I have access.

The 7 cases about to be recorded are of interest not only because they represent the largest single series which has so far been reported, but because they illustrate three varieties of appendiceal intussusception. One demonstrates how an intussusception may originate by the prolapsing of the appendix mucosa around a concretion which it is attempting to extrude, a mode of onset first suggested by Rolleston in 1898 when he published a similar case. A second case illustrates the simplest form of appendix intussusception in which the distal part of the appendix is invaginated into its proximal portion. A case of intussusception of an appendix mucocele is also included, only 5 other cases of which have been found in the literature. Of the remaining 4 cases, 2 are examples of the partial variety of intussusception of the appendix into the cæcum, and 2 illustrate the further stage, namely, complete inversion.

HISTORICAL

The first case of intussusception of the appendix to be mentioned in the literature was that of McKidd (1859), and was reported in the *Edinburgh Medical Journal*. It was that of a boy, aged 7, who for two months before his death suffered from the most excruciating central abdominal colic. The colic was so severe that he required gradually increasing doses of morphia so that before his death he was receiving several grains a day without relief, with almost constant chloroform anæsthesia also to supplement it. Throughout, his bowels had acted well; there was no blood passed per rectum, and only in the last few days did he experience pain in the right iliac fossa. It is interesting to note that in this, the first case of intussusception reported, there was a history of infestation of his intestines with worms. Unfortunately the post-mortem findings are not clearly portrayed, nor is the drawing very helpful. It would seem that the inverted appendix had carried in the caput cæci with it to such an extent that the lower wall of the ileum was continuous with the lower edge of the cæcum, the inverted appendix lying across and obstructing the ileocæcal valve.

The second case was in 1888 and was reported by Chaffey. This was also a post-mortem finding in a thin boy, aged 3, who had a history of eight weeks' colicky abdominal pains, gradually increasing in severity, with, at a late stage, vomiting and the passage of mucus and blood per rectum. Autopsy revealed intussusception of the proximal end of the appendix and, as in the case of McKidd (1859), a partial intussusception of the caput cæci.

In 1890 Knight reported the first operation for this condition. The case was a baby of 13 months who had a partial intussusception of the appendix as well as an intussusception of the ileocæcal valve. Death occurred one hour after operation.

Another early unsuccessful operation was reported by Waterhouse in 1895, on a female, aged 4, who lived for 30 hours. This case was obviously a fully developed intussusception of compound type, in that there was an intussusception of appendix as well as the more common intussusception of the ileocæcal valve. At operation the ileocæcal intussusception reduced easily, but there was left an intussusception of the appendix, only half an inch of its distal end being visible, the rest being palpable within the cæcum as a spherical swelling 1 in. in diameter. In attempting to reduce the intussusception the cæcum burst, forcing him to excise the cæcum and anastomose the ileum to ascending colon. In this specimen the appendix was gangrenous.

McGraw (1896) reported the first operative survival. For four months the patient, a boy aged 7, had periodic attacks of typical colic with vomiting, and the passage of blood and slime per rectum. Here again, although only the appendix and caput cæci were found intussuscepted, a large recurrent intussusception had been developing, the ascending and transverse colon being found acutely red and congested at operation. A point of considerable interest was the situation of the appendix which was inserted into the cæcum at the fœtal site. The neck of the intussusception was incised and the intussusception was removed, the cæcal opening being closed by a continuous suture which was covered over by omentum. The child made an uninterrupted recovery.

One year later, in 1897, other successful operations were reported by Wright and Renshaw and also by Pitts.

The first publication illustrating intussusception of mucocele of the appendix is to be found in the *Clinical Journal* of 1919. The article was written by McLennan, and in it he described 2 cases in which he had found this condition, in one of which the pre-operative diagnosis of

intussusception of mucocele of the appendix was suggested. Since that time one has been able to find published reports of only 4 other cases of mucocele of the appendix (Hall, 1934; Jones and Carmody, 1936; Morgan, 1937; Mulsow, 1930).

AETIOLOGY

Many theories have been put forward to explain the development of intussusception of the appendix. In the first few cases there could only be speculation as to its origin. McKidd (1859) noted the presence of worms, but gave no comment suggesting how the intussusception had occurred. Chaffey (1888) thought that the intussusception in his case had resulted from the contraction of old adhesions between the ileum and cæcum. McGraw (1897) sought explanation in a complicated theory of irregular colonic and cæcal muscular contractions. In his view, if the cæcum was in spasm at the same time as the longitudinal muscles of the colon, intussusception of the appendix could occur if the cæcal spasm still remained and a sudden release of the longitudinal muscles took place allowing the colon to overshoot and infold the contracted end.

The first real light shed on the aetiology came with the publication of Rolleston's case in 1898. The specimen in this case was a post-mortem finding in a case of peritonitis following duodenal ulcer perforation. Examination of the appendix revealed a concretion firmly gripped by appendix mucosa projecting into the cæcal cavity—i.e., there was a prolapse of proximal appendix mucosa into the cæcal cavity, the prolapse occurring around a concretion which the appendix was attempting to extrude. That an intra-cæcal prolapse of all the coats of the appendix did not occur may well have been due to the fact that the appendix was fixed to peritoneum by old adhesions. This case pointed out one of the essential factors in the aetiology of intussusception of the appendix, namely, that it might develop from an attempt on the part of the appendix to extrude a foreign body from within its lumen. Such a foreign body might be causing irritation, such as a concretion as in Rolleston's case, or worms as in McKidd's. A similar case to that of Rolleston's is included in the present series. Again, if this be so, it is reasonable to assume that any projection from the appendix wall into the appendix lumen would be dealt with in a similar fashion to a foreign body—for example, if a papilloma of the appendix mucosa projected into the appendix lumen, it, too, would be subjected to attempts at expulsion.

Further, it is known that the appendix is capable of rhythmic peristaltic contractions. Gunn and Whitelocke (1914) reported a series of experiments illustrating these peristaltic contractions in the isolated human appendix. If a recently removed appendix which has been preserved in Ringer-Locke solution is placed in a bath of solution heated to 33° C., peristaltic contractions recommence and can be demonstrated on the kymograph: the more normal the appendix the better the contractions obtained. I have recently repeated and confirmed these experiments during the preparation of this paper. Similar results were obtained by Dennis (1941) in experiments on over 289 appendices. Harris, Bently, and Blacklock (1930) reported a series of experiments on the exteriorized appendices of dogs and found peristalsis extremely vigorous, probably more so than in man.

That this peristalsis does occur has been confirmed in several published articles and has been seen by the majority of surgeons at some time or other, usually as an incident in the course of an abdominal operation for some other condition.

In this connexion McDermott (1931) speaks of Alvarez's Kodak film of intestinal movement as an excellent pictorial record of such appendiceal peristaltic contractions. He also quotes a case operated on by Myles for a cæcal hernia in which the appendix was undergoing active peristalsis and was repeatedly intussuscepting into the cæcum and undergoing spontaneous reduction. Similar cases have been reported by Monod (1905).

That the appendix is an organ capable of individual peristalsis is an accepted fact, and it is liable to undergo active contractions to extrude a foreign body or anything simulating the physical character of a foreign body. Naturally successful expulsion may be impossible if the base of the appendix is constricted.

A number of the cases give evidence of such a foreign body—for example, the concretion in Rolleston's case and in Specimen 5 in the present series; worms in the cases of McKidd (1859), Hohmeier (quoted by Do Couto, 1925), McSwain (1941), and others. Five cases (Blaxland, 1920; Burghard, 1914; Szenes, 1922; Wright and Renshaw, 1897) had a polyp or papillomatous tumour at or near the proximal end of the appendix. All these cases would seem to have adequate predisposition for initiating excessive peristaltic contractions on the part of the appendix.

In the same way, once the appendix has become partly or wholly inverted it will constitute a foreign body within the cæcum, which in its turn will in all probability commence to contract in order to pass the foreign body on, and, if successful, will cause a compound intussusception to develop with inversion of the ileocæcal valve and ileum, a complication which has frequently occurred.

In many cases of intussusception, however, there is no such positive finding as a foreign body, though some of these may have been initiated by a concretion which, once intussusception has occurred, is passed on and is later voided. In these cases it would seem that McLennan's view is the most acceptable, namely, that a nodule of inflammatory tissue develops at the base of the appendix and causes a buckling inwards first of the mucosa and later of all its coats at that point, with the ultimate development of an intussusception.

McLennan (1919) goes further and expresses the belief that intussusception at the ileocæcal region is initiated in a similar manner. He also thinks that this nodule is inflammatory in origin, and he supports this belief by pointing out that all the cases of ileocæcal intussusception on which he has operated have had enlarged mesenteric glands. In one case of recurrent right iliac fossa pain he describes the discovery of just such a thickened nodule of the cæcum buckled inwards which had caused an intussusception; when it was reduced it at once recurred, the development of a full-scale intussusception being prevented by lack of mobility of the cæcum. This is a view which is related to that expressed by Wakeley (1939), who considers that the increased lymphoid tissue that one finds in the terminal ileum and appendix in young children acts as a foreign body and gives rise to increased and irregular peristalsis of bowel and appendix which sometimes culminates in intussusception; it being remembered that two-thirds of the cases of intussusception occur in young, often very young, children.

In a certain proportion of the cases it is probable that the intussusception has been preceded by an acute attack of appendicitis, which attack has left a thickening of the appendix wall at or near its base, localized in such a way as to give rise to the foreign-body effect necessary to the onset of vigorous appendiceal peristalsis and the possibility of subsequent intussusception.

In 5 of the cases, including those of Thomson (1911), Kelly (1909), and Connor (1903), a blow on the abdomen was reported, usually a week or ten days previously to the operative finding of intussusception. It is impossible to say whether the trauma was directly responsible for the intussusception or not, but it does seem possible that it might have given rise to an area of inflammation at the base of the appendix similar to that suggested by McLennan (1919).

In discussing the aetiology of intussusception of appendix, the work of McDermott (1931) must be considered. He performed extensive anatomical studies of the base of the appendix and found there a muscular sphincter resembling in many ways the ileocæcal valve. He thought that spasm of this valve would give rise to a hard mass at the base of the appendix, which would act as the apex of an intussusception by the peristaltic action of the appendix. He goes further and expresses the belief that intussusception is much commoner than is reported, that spontaneous reduction frequently occurs and may take place on simple laparotomy. He quotes the findings of Myles and Alvarez mentioned above.

Lastly, several cases of intussusception of the appendix stump have been reported where the appendix had been previously removed, and in which the stump (usually too large) had been inverted.

In regard to the aetiology of intussusception of mucocele of the appendix, it is interesting to note that whereas simple appendiceal intussusception occurs most commonly in children, intussusception of mucocele of the appendix has been reported only in adults of the average age of thirty-five. (McLennan (1919) does not give the ages of his cases, but it would appear that they were both well into adult life.) The explanation of this higher age incidence may well be found in Phemister's view (quoted by Morgan, 1937) as to the aetiology of the simple mucocele of the appendix. He believes that there is a direct relationship between the development of mucocele and what he calls the normal involution of the appendix, occurring usually between the ages of 35–50, that being the period at which retrogression and obliteration of the appendix lumen commonly occurs. One cannot accept this obliteration of the appendix as being a universal event, as it is well known that acute appendicitis can and does occur in some elderly patients and is on occasion seen in the very old, but it is conceivable that such involution does occur in many cases as he suggests. If this involution occludes the appendix lumen near its base, while the mucosa distally is still actively secreting, mucocele of the appendix may follow. Similarly, a mucocele of the appendix may develop following an acute attack of appendicitis in which fibrosis near the base of the appendix occurs after the subsidence of the acute attack. Tumours at the base of the appendix may also give rise to mucocele. Once the mucocele has developed and the tension within it rises, the thin diaphragm at its base will tend to be pushed into the lumen of the cæcum and thus show the first stage of a potential intussusception.

MORBID ANATOMY

In considering the aetiology of intussusception of the appendix, various predisposing factors were discussed. It was seen that the intussusception might be initiated by the action of some irritating factor such as an enlarged lymph-follicle, a papilloma, or round worms. If this irritation was situated exactly at the base of the appendix an intussusception, if it developed, would occur at the junction of the appendix with the cæcum; if, however, it were more distally placed in the appendix, the intussusception would be one of distal appendix into proximal. A few examples of this latter variety have been reported, usually in cases in which the intussusception had progressed further by the time of operation, and in which this type of intussusception was discovered only after reduction of the main mass during the course of the operation. Only in one case, reported by Whitrow (1930), is there reference to this type of onset uncomplicated by further progression of the intussusception. A similar case is reported in this series. In any attempt at producing a classification of intussusception one must include this type as one possible variety despite the apparent rarity of this mode of onset. Once developed it may progress to one of complete inversion of the appendix, or it may give rise to a compound intussusception, or both.

In the vast majority of cases the process starts at the junction of the appendix with the cæcum so that the intussusception is first formed by the base of the appendix prolapsing into the cæcum. There are now two possibilities: either the intussusception will go so far and then be arrested with the appendix partially intussuscepted, or else the appendix will become completely inverted into the cæcum. In this second group almost half the cases come under either one or other of these possibilities.

In the third main group those cases are usually classified in which the intussusception progresses and reaches the ascending colon, ileum, or further. A third of the cases come under this heading. This variety is referred to as compound intussusception. Were it not for this group, intussusception of the appendix would lose almost any claim it may have to surgical importance and become one more of the surgical curiosities. It is this tendency to lead to a compound intussusception that makes it desirable that the condition should be borne in mind and remembered in considering the diagnosis in those cases in which there is a history of colicky central abdominal and right iliac fossa pain characterized by short spells of complete well-being between the attacks of colic. The mortality-rate found by McSwain (1941) for intussusception of the appendix of compound type was 14·8 per cent, while that of simple intussusception of the appendix was only 2·6 per cent. In this group the intussusception of the appendix will be masked and will not be apparent until either the compound intussusception is reduced at operation, revealing the intussusception of the appendix (which latter is usually found to be irreducible), or it will only be discovered post-operatively when the resected specimen comes to be examined. The extent to which the intussusception has progressed will depend on the length of time it has been allowed to persist. The apex may be found at the hepatic flexure, in the transverse colon, or even projecting at the anus. The last-named state of affairs was found by Burghard (1914) in his case. He describes how he operated on a man of 60 for what he thought was a prolapsed polyp at the anus. After removing the supposed polyp he found that it was a completely inverted appendix, the apex of a gross intussusception; incidentally the appendix was found to have a small papillomatous tumour at its base. Corbett (1914) found the intussuscepted appendix in his case had been passed into the ileum.

In Thomson's first case 1 in. of the tip of the appendix was found buried in the lateral wall of the cæcum. It does not seem right that this type of case should be included as a case of true intussusception.

Kelly (1909) and Moschowitz (1910) both include in their classification massive intussusception in which the appendix and cæcum are carried along with the intussusception, but are still in normal relationship to one another. Obviously this is not a true appendiceal intussusception and should not, therefore, be included. It is, however, only fair to say that Szenes (1922) is of the opinion that the appendix may be forcibly turned inside out in a few cases of massive intussusception when the apex becomes held up. He believes that when this happens the continued peristalsis of the outer tube may forcibly evert the cæcum and then the appendix.

In regard to the morbid anatomy of the cases of mucocele of the appendix, it is characteristic that the appendix in this condition is usually large, in Hall's (1934) case being 17 cm. long and 4 cm. in diameter. As a rule, there is no communication between the appendix lumen and the cæcum. Marked muscular hypertrophy of the appendix is a feature. The vessels are injected, dilated, and tortuous, standing out prominently as they course over the appendix wall. Diverticula are not infrequently present in the mesentery of the appendix. When the appendix is opened it is found to be filled with translucent yellowish, gelatinous material.

Lastly, 4 cases of intussusception of the appendix stump have been reported, the time-lag following appendicectomy varying from 12 days in Rouquette's case to 4½ years in one of McLennan's cases. Rouquette (1914) had operated on his case 12 days previously for ileocæcal intussusception. He had reduced the intussusception and removed the appendix, burying its stump with two purse-string sutures. By the twelfth day the child had redeveloped the clinical picture of intussusception and had a mass at the splenic flexure. In attempting to reduce the intussusception the cæcum burst, revealing a polypoidal tumour, the apex of which was the grossly congested stump of the appendix. Barton McSwain's case was even more interesting. A boy of 19, who was supposed to have had his appendix removed at the age of 5, presented the clinical picture of a subacute intussusception. At operation the ileocæcal valve was found intussuscepted as far as the splenic flexure. On reducing the intussusception the appendix was found to be partially intussuscepted into itself, and was removed by appendicectomy. The patient returned in one month with a recurrence of his symptoms. He became gradually worse and eventually required a further operation which was carried out three months after the first. On this occasion the operation revealed an intussusception at the hepatic flexure, which he was able partly to reduce. On opening the cæcum he found that the apex of the intussusception was the appendix stump. These 2 cases and 2 similar cases described by McLennan (1935) would appear to strengthen the argument of those, led by the Mayo Clinic (Horsley and Bigger, 1937), who advocate burying the stump under a convenient tag of fat, rather than inverting it into the cæcum with the aid of a purse-string suture.

Before leaving this subject of stump inversion it is perhaps of interest to turn back the pages of the *American Journal of the Medical Sciences* to

1895 and to read of the method used by George Edebohls in dealing with the stump. In his time it was apparently customary to leave the appendix stump lying free in the peritoneal cavity. As he was afraid that this might spread the infection further he advocated that, after ligating the mesentery, the entire appendix be turned inside out into the cæcum. If there happened to be a constriction near the base of the appendix which would effectively prevent its complete inversion he advocated removal of the distal portion followed by inversion of the remaining stump. Further, he advised that all normal appendices found during abdominal operations be routinely inverted. He concluded by stating that he was quite indifferent to the fate of the appendix thus dealt with. He felt that whether it lived or sloughed off it was out of harm's way. In actual fact quite a large portion frequently lived; for example, Furniss (1908) re-operated on a case in which he had inverted a normal appendix six years previously, and found that ¾ in. of the appendix was still present within the cæcum.

In this, like so many other surgical procedures, the pendulum of surgical technique would appear to have swung towards the other extreme. That there are still some who advocate inversion of the entire appendix after ligation of its mesentery in all laparotomies is evidenced in an article in the *Presse médicale* by Filho, Professor at Rio de Janeiro, as recently as 1923, but for the majority of surgeons the choice is now the complete removal of the appendix at its base, ligation of its stump, and either burial of the stump beneath a tag of omentum or fat, or else its inversion into the cæcum.

Tabulation of Cases

Of the total of 82 cases reviewed and included in this paper, the pathological classification resulted as follows :—

1. Intussusception of the appendix into itself		2
2. Intussusception of the appendix into the cæcum :		
a. Partial	29	
b. Complete	8	44
Into cæcum, but data incomplete	7	
3. Compound intussusception, where the intussuscepted appendix passes into the ascending colon or further		32
4. Appendix stump inversion		4
Total		82

CLINICAL FEATURES

Commonly this condition occurs in children, and sometimes very young children, but, as has already been indicated, quite a number of the cases occur in adolescents and adults.

The clinical history may show that the condition has been present for only a few hours, but, as a rule, it covers a much longer period of time and averages several months in duration. In a straightforward case of simple intussusception of the appendix there is typically a history of central abdominal colic accompanied in some cases by pain in the right iliac fossa. The colic is characteristic in its severity, lasting, as a rule, for one to three minutes at a time, though on occasion it may last for as long as a quarter of an hour, and is at once followed by a period of perhaps several hours of freedom, during which there is a feeling of complete well-being, with good appetite and physical activity. Many of the cases give an additional history of pain in the region of the small of the back aggravated by standing up or by lying on the right side, the two cases described by McLennan (1919) being illustrative of each of these types of back pain.

Vomiting occurred in many of the cases, and, as one would expect, it was a more obvious feature in those cases in which the intussusception had become compound in type with invagination of the ileocæcal valve into the ascending or transverse colon or farther. Similarly a few had as a feature the passage of blood per rectum, and others the passage of slime, this being a common finding in the cases of compound type. Loss of weight was frequently noted in those cases in which the condition had been present for some time.

There was a moderate rise of temperature in some of the cases, usually in those in which there was evidence of some inflammatory change in the appendix. As one would expect, a rise of temperature was the rule where the intussusception was already compound.

On examination, the abdomen was found in many cases to be free from rigidity, though where there was inflammatory change in the appendix, rigidity in the right iliac fossa was often well marked, resulting in a diagnosis of acute appendicitis being made. In the absence of rigidity a mass was frequently palpable in the right iliac fossa, usually just above McBurney's point. It was slightly tender on palpation, and usually found to be freely mobile, unless it was bound down by adhesions.

X-ray examination may be of definite value in arriving at the correct diagnosis. In the case of Hall (1934) a barium enema showed a small filling defect at the cæcum, which might have given the diagnosis had it not been that clinically the mass was rather higher than usual in situation and was mistaken for an enlarged gall-bladder. Skarby (1941) publishes a case with correct preoperative diagnosis based on careful X-ray studies, and includes in his paper very clear radiographs of the condition seen in the case published. Further, when a remission of symptoms occurred and a second X-ray examination was carried out, it was found that the intussusception had undergone spontaneous reduction. In McLennan's second case a filling defect was found in the cæcum and the condition of intussusception of the appendix was suspected.

In Jones and Carmody's case (1936) the barium enema was seen to reduce an intussusception which had reached the transverse colon. The intussusception was not, however, diagnosed as such, and was reported in the following terms : " There is an apparent inspissated fæcal mass in the ascending colon which shifted into the

cæcum ", and also that " the colon is very spastic and the enema reproduced the patient's abdominal distress ". Presumably the " inspissated fæcal mass " was still present in the cæcum at the end of the X-ray examination, in which case a correct diagnosis might well have been arrived at had the condition not been so rare, and so presumably never thought of by the authors. In *Case* 3 in this paper, on X-ray examination by barium enema it was found that the cæcum did not fill, while a barium meal follow-up showed some delay in the terminal ileum and it was not possible to state the precise cause. As a mass was palpable in the right iliac fossa below this site of delay, it was suggested that there might be an abnormal communication between ileum and ascending colon.

From consideration of these 5 cases it will be seen that X-ray examination by barium enema could be of great assistance in diagnosing this rare condition, provided that when such a filling defect in the cæcum is encountered the possibility is borne in mind.

Once the intussusception becomes compound the clinical picture changes to one of bowel obstruction with vomiting, some abdominal distension, and a mass palpable in the ascending or transverse colon or further distally.

Few of these cases are correctly diagnosed, mainly because they are rare and therefore not considered. Fortunately the condition runs a chronic course which may last for several months before being complicated by intussusception of bowel. The outstanding clinical feature is the colic, which is brief, but of great severity, and characterized by periods of complete freedom from pain. In many cases a mass is palpable in the right iliac fossa, tender, but freely movable. Finally, X-ray examination may be of great value.

TREATMENT

When the Appendix is Partially Intussuscepted.—It will usually be found possible to reduce the intussusception by simple manipulation, squeezing the cæcum combined with gentle traction on the appendix. Thereafter appendicectomy may be performed in the usual way. If reduction does not succeed by simple means, it may be achieved by finding an artificial line of cleavage, such as can be obtained by incising the muscle coats of the appendix, and by blunt dissection separating the intussusceptum from the intussuscipiens. If this is found to be possible, and it usually is, simple pressure on the intracæcal portion will now bring about reduction, the appendix being fliped from its muscle coats at its proximal end. Here again simple appendicectomy will be all that is required. If the intussusception is large, and the appendix is broad at its base, it may be found necessary to use small clamps in the removal of the appendix, the cæcum being closed by means of a running suture. Where it is found impossible to attain reduction, treatment will be along similar lines to that for complete intussusception.

When the Appendix is Completely Intussuscepted.—Treatment under these circumstances will usually be based on some form of incision of the cæcal wall. As a rule, it will be found most convenient to incise one of the longitudinal bands, the incision diverging to sweep round the appendix, thus removing a small cuff of the cæcum with the appendix, the opening in the cæcum being closed by a running suture which is in turn inverted by a further stitch.

When there are massive adhesions around the cæcum and appendix it may be necessary to excise the cæcum as well as the appendix, leaving if possible the ileocæcal valve untouched. Occasionally it has been found necessary in such cases to perform a much more extensive resection such as a right hemicolectomy as was required in Boppe's case (quoted by Do Couto), a somewhat similar resection being necessary in the cases reported by Haasler (1902), and McConnell and Wilson (1914).

When the Intussusception is Compound.—In these cases it appears to the operator that the condition is a straightforward ileocæcal intussusception, and he proceeds in the usual way to attempt reduction. If complete reduction is attained the intussusception of the appendix becomes at once apparent, and will be dealt with as the circumstances of the case demand. If complete reduction is not attained, treatment will resolve itself into the treatment of ileocæcal intussusception, probably consisting of some form of resection, no direct treatment of the appendiceal intussusception being called for.

CASE RECORDS

Case 1.—MUSEUM SPECIMEN. This is a post-mortem specimen in the museum of the Pathological Department of the Western Infirmary, Glasgow.

CLINICAL HISTORY.—The patient was admitted to the Western Infirmary in 1909 with a history of acute appendicitis of five days' duration, with a temperature of 100·6° F., pulse of 128, and respirations of 40. His condition became rapidly worse and he became delirious and eventually died. In addition to the symptoms of appendicitis he had the physical signs of consolidation of the lower lobe of the right lung, and of pericarditis. There was also albuminuria.

AUTOPSY.—At post-mortem marked distension of the intestines was found, but no evidence of general peritonitis. The appendix was lying in the retrocæcal position in an advanced state of inflammation, several areas showing gangrenous change. There was an extensive area of cellulitis around the appendix, which was found to pass upwards behind the right kidney and adrenal, and also behind the liver. Evidence was also found of early fibrinous pericarditis, and two pints of pus were found in the right pleura.

THE SPECIMEN (*Fig.* 25).—On the posterior aspect of the cæcum a typical acute gangrenous appendix was found, with, in addition, retroperitoneal suppuration. The anterior wall of the cæcum has been cut away. Into the interior of the cæcum there projects a large concretion which has completely blocked the lumen of the appendix. The concretion is still firmly gripped by the appendix mucosa, a cuff of which has prolapsed into the cæcum. It is in this prolapse of

the mucosa that the interest of the specimen lies. The prolapse has occurred as a result of attempts on the part of the appendix to extrude the concretion from its lumen. It would appear that the other coats of the

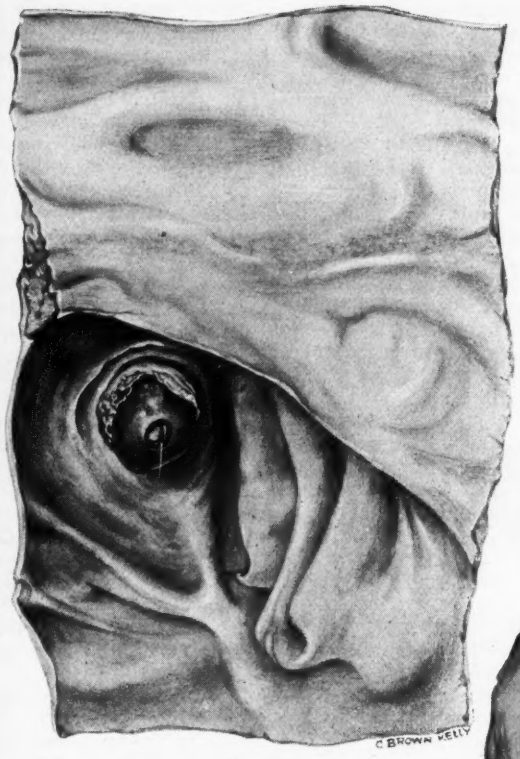

FIG. 25.—*Case* 1. The anterior wall of the cæcum has been removed to show a concretion projecting from the appendix lumen. Note the prolapsed cuff of appendix mucosa firmly gripping the concretion.

appendix have not become involved in the prolapsing process, presumably because of the fixation of the appendix retroperitoneally. The specimen is exactly similar to that published by Rolleston in 1898, and it illustrates what may well be the aetiological factor in many cases of intussusception of the appendix. The appendix in an attempt to rid itself of a concretion becomes the seat of active peristalsis, and in doing so its mucous membrane grips the concretion to pass it on. In this way the mucosa at the proximal end of the appendix may become inverted into the cæcum without the muscular layers becoming involved. With further peristalsis and possibly with the advent of œdema of the prolapsed cuff of the mucous membrane, the muscular layer may also be dragged into the cæcum to give the commencement of an intussusception of all the appendix coats. Most authorities are agreed that this is one way in which intussusception of the appendix may be initiated.

Case 2. Mr. HUTTON's case.

HISTORY.—Four months previous to being seen by Mr. Hutton, the patient, a female, aged 75, went to her own doctor because of a feeling of uselessness. The doctor examined her blood and told her that she was suffering from anæmia. Two months later she developed a severe pain in the right side of her abdomen and on being examined her doctor found a 'lump' there. She stated that her bowels had been regular, though on occasion she required to take a little medicine. She suffered at times from flatulence, but had no other dyspeptic symptoms.

ON EXAMINATION.—Examination revealed a hard irregular mass in the right side of the abdomen, lying well clear of the costal margin and below the edge of the liver. It was diagnosed as a carcinoma of the hepatic flexure. X-ray examination by means of a barium enema confirmed this diagnosis by showing a fairly gross filling defect at that site. The barium passed beyond the tumour and entered the terminal ileum.

OPERATION.—The abdomen was opened through a right rectus incision. A ring carcinoma of the ascending colon was found just proximal to the hepatic flexure, while about eight inches distally there was a large diverticulum of the transverse colon. It was also noted that the appendix had intussuscepted into itself at its base. A right hemicolectomy was carried out, the bowel continuity being restored by a lateral anastomosis, and the abdomen was closed.

She made an excellent recovery.

FIG. 26.—*Case* 2. Intussusception of the appendix into itself.

THE SPECIMEN (*Fig.* 26).—There is a typical ring carcinoma of the ascending colon, one edge of which can be seen presenting at the window which has been cut in the specimen. The window also reveals a

FIG. 27.—*Case* 3. Partial intussusception of the appendix into the cæcum.

polypoidal tumour situated three inches distal to the carcinoma, while distal again to this there is a diverticulum of the colon.

The present importance of the specimen lies in the fact that the proximal half-inch of the appendix has intussuscepted into itself.

Case 3.—Mr. GALBRAITH'S case.

HISTORY.—A female patient, aged 71, had complained for some time of abdominal colic which started in the right iliac fossa and radiated across the abdomen. One week prior to being seen she experienced a very severe attack, which was associated with nausea but not with vomiting. This attack lasted for two days and then passed off, and she had no further pain. Her appetite had been good and her bowels had been regular, no abnormality being noticed in the stools. During the previous six months she had lost about 14 lb. in weight.

ON EXAMINATION.—She was found to be fresh complexioned, thin, but appeared younger than her years. Abdominal examination revealed a sausage-shaped mass of soft consistency in the right iliac fossa. It was dull on percussion and freely movable. No other abnormality was detected.

X-ray examination was carried out. The barium meal showed considerable holding up at the ileocæcal valve, but eventually the barium was seen to pass through into the cæcum. Barium enema showed that the cæcum did not fill properly. In view of these findings and the palpable mass in the right iliac fossa it was suggested that there might be an abnormal communication between the terminal ileum and ascending colon. If the X-ray picture shown in *Fig.* 28 is compared with the specimen it will be seen that there is a filling defect on the inner wall of the cæcum which corresponds to the intussusception of the appendix. The ill-defined appearance of this filling defect might have suggested the diagnosis had it not been so unusual.

OPERATION.—Six days later operation was carried out through a right rectus incision. An enlarged thickened cæcum was found to contain a soft pulpy mass in which the appendix and terminal portion of the ileum were involved, both the root of the appendix and the terminal ileum being indrawn into this mass. The ascending colon was folded forwards in front of the cæcum, to which it was fixed by fibrous adhesions, the transverse colon starting from the region of the cæcum. This mass was thought to contain a tumour, and as no enlarged glands were found in the mesentery or in the region of the aorta, and as there was no evidence of secondary nodules in the liver or other contra-indication, a right hemicolectomy was performed, bowel continuity being restored by an end-to-side anastomosis, and the wound was closed.

She made an uneventful and uninterrupted recovery.

THE SPECIMEN.—After fixation the specimen was opened, revealing the appearances shown in *Fig.* 27. The anterior wall of the cæcum was cut away revealing an intussusception of the proximal end of the appendix into the cæcum, this being the intracæcal mass felt at operation. The anterior portion of this mass was removed, and in doing so the appendix was cut across tangentially. The specimen will be seen to consist

FIG. 28.—*Case* 3. The arrows point to the filling defect in the cæcum corresponding to the intussusception of the base of the appendix.

of the terminal few inches of ileum, cæcum, ascending colon, and the proximal portion of transverse colon. The ileum is entering the cæcum immediately behind the intussusception, and is somewhat obstructed, though not actually occluded by it. The intussuscepted portion of the appendix is much swollen by œdema. Histological examination of the specimen shows, as one would expect, necrosis of the appendix mucosa, but no evidence of tumour tissue.

Case 4.—Mr. CAMPBELL'S case. (Specimen No. 237a: Intussusception of vermiform appendix.)

This specimen, which was removed at operation many years ago by Mr. Campbell of the Western

FIG. 29.—*Case* 4. Partial intussusception of the appendix. (× 2.)

Infirmary, Glasgow, is in the Pathological Department, Western Infirmary. Unfortunately it has not been possible to trace the case and obtain the relevant clinical data.

THE SPECIMEN (*Fig.* 29).—This has lost most of its colour; it is, however, a typical example of the partial or incomplete type of intussusception of the appendix. About two-thirds of the appendix has been involved in the intussusception process, one-third remaining free but somewhat inflamed. The mucous membrane at the apex of the intussusception would appear to have been the seat of acute inflammatory change and in places seems to be almost gangrenous.

The appendix has been removed along with a small cuff of cæcal wall.

Case 5.—Mr. HUTTON'S case.

HISTORY.—This patient, a female aged 42, was admitted to hospital complaining of pain in the right lower abdomen. For one year she had suffered from recurring attacks of pain. This pain was of short duration and was stated to pass through to the small of the back, at which site there was, in addition, a constant aching pain. The attacks were becoming more frequent, and with each attack she vomited. It appears that the bowel movements were regular and the stools showed no abnormality; that there was no urinary upset and that the periods were normal.

ON EXAMINATION.—Temperature, pulse, and respiration were normal. Examination of the abdomen revealed an area of tenderness below and to the right of the umbilicus; there was no rigidity and no mass was palpable. The leucocyte count was 17,000. The patient was kept under observation for several days, and as the tenderness persisted it was concluded that the appendix was inflamed and appendicectomy was decided upon.

OPERATION.—She was operated on by Mr. Hutton, a Battle's incision being used. The operation notes read as follows: "There was no sign whatever of the presence of an appendix. On clearing the cæcum a blood-vessel was seen running into it where the appendix should have been. In the lumen of the cæcum at this point a small mass was felt; this was presumed to be a completely intussuscepted appendix." A clamp was applied to the cæcum, a portion of which and the mass was removed. The cæcal opening was closed. Apart from an intramural fibroid, the pelvic organs were found to be normal. The wound was closed. Recovery.

FIG. 30.—*Case* 5. Complete intussusception of the appendix. (× 2.)

THE SPECIMEN (*Fig.* 30).—Examination of the specimen revealed that the appendix, which was small, was completely inverted. In the figure the small completely inverted appendix can be seen to be deeply congested though not actually ulcerated. The fringe of tissue at its base is the portion of cæcum along with which the appendix was removed. The mesentery of the appendix can be seen to run into the intussusception, it being the vessel in this mesentery which led to the discovery of the appendix, and to the fact that it was intussuscepted.

Case 6.—Mr. MATTHEW WHITE'S case.

HISTORY.—Male, aged 4¼ years, was admitted to hospital with a history of recurrent attacks of abdominal colic of two months' duration. These attacks were not severe, but lasted from one to two hours. There was no history of vomiting and the bowels had been regular. Ten days before admission he began to vomit after food, but this was stopped by giving a stomach mixture. While under observation in hospital he had several attacks of slight abdominal pain, but never vomited, and his pulse remained regular.

ON EXAMINATION.—A sausage-shaped mass was found lying horizontally across the abdomen. This mass seemed to vary in size and shape, and on occasion it was found to have disappeared. A barium meal investigation was carried out on several occasions. On one of these a filling defect in the colon was reported, and a chronic intussusception or polypus was suggested as the possible diagnosis.

OPERATION.—Laparotomy was performed. The cæcum was found to be covered with organized lymph and showed the presence of numerous recent adhesions. The appendix could not be found, but a dimple was present where the base of the appendix is normally situated, and on palpating the cæcum the appendix could be felt inside it. The cæcum was opened and a completely fliped appendix was found and removed, the cæcum thereafter being closed.

The patient has made a good recovery and has been well since operation.

Case 7.—AUTHOR'S case.

HISTORY.—A female patient, aged 30, was admitted to the Western Infirmary, Glasgow, on May 12, 1941, with severe abdominal pain of of two-days' duration. For two years she had suffered from attacks of diffuse central abdominal pain, gnawing in character, and unrelated to food. These attacks would last for a few hours to as long as four weeks at a time, with periods of remission of equal variability. The pain appeared to increase in severity with each attack. During the week immediately preceding admission to hospital she developed pain in the right iliac fossa, which gradually increased in severity until two days before admission it became suddenly very much worse. This pain was of a colicky nature causing her to roll about, but from which she could get no relief. During these two days she suffered from nausea, but she did not actually vomit. Her bowels had always been regular, and she gave no history of upset of micturition.

In her previous history there was a story of her having had an attack of ' colitis ' one year previously. This attack lasted for one month and was accompanied by pain and the passage of blood on defæcation.

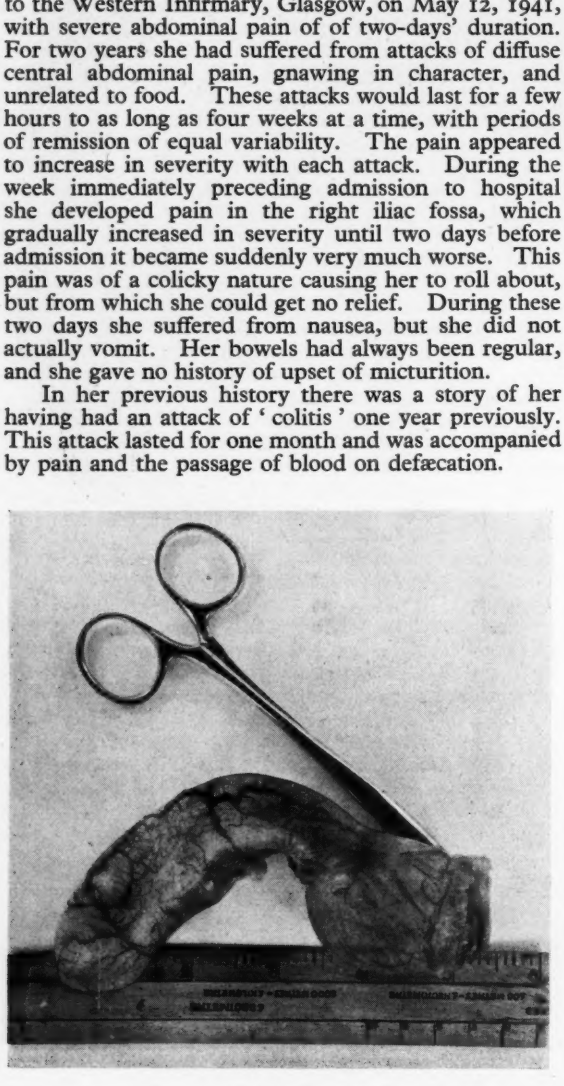

FIG. 31.—*Case* 7. Partial intussusception of mucocele of appendix.

ON EXAMINATION.—On admission her temperature was 98·6° F. and her pulse was 108. Her general appearance was that of a pale, fairly well nourished, but neurotic woman. Her tongue was heavily furred and her breath was heavy. Abdominal movement during respiratory excursion was practically nil. Palpation of her abdomen revealed generalized guarding with rigidity in the right iliac fossa, where tenderness was well marked, especially over McBurney's point. There was also slight tenderness in the left iliac fossa. There was no dullness in the flanks and no diminution of liver dullness was noted. Examination of the chest revealed some diminution of respiratory murmur at both bases, but no adventitial sounds were heard.

The diagnosis of acute appendicitis was made and she was operated on almost immediately.

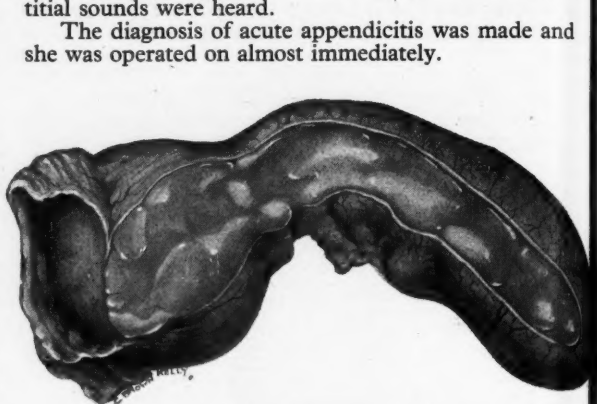

FIG. 32.—*Case* 7. Partial intussusception of mucocele of appendix. The specimen opened.

OPERATION.—The abdomen was opened by a Battle's incision and there at once presented itself one end of a large oblong, slightly curved, cystic swelling. Further investigation revealed that it was a huge cystic appendix. On delivering the cæcum into the

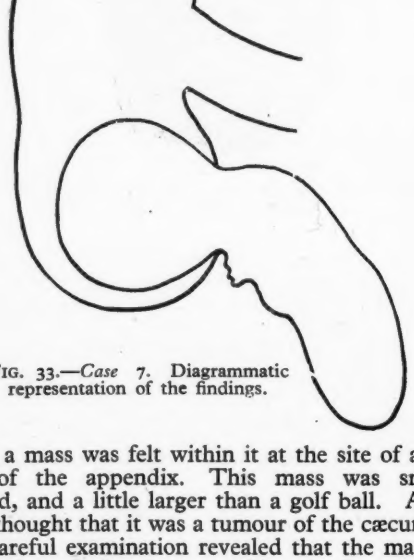

FIG. 33.—*Case* 7. Diagrammatic representation of the findings.

wound a mass was felt within it at the site of attachment of the appendix. This mass was smooth, rounded, and a little larger than a golf ball. At first it was thought that it was a tumour of the cæcum, but more careful examination revealed that the mass was also cystic and that it appeared to be in continuity with the appendix, and thus the true nature of things became apparent, namely, that the base of the cystic appendix had intussuscepted into the cæcum. That the intussusception was not recent was obvious from the presence of thin fine adhesions between the cæcal intussuscipiens and the appendix, and from the absence of acute inflammatory changes on either the cæcum or the appendix, although the vessels showed marked congestion and dilatation.

The adhesions around the neck of the intussusception were separated by blunt dissection, and a plane of cleavage was sought for by insinuating a

director between the intussusceptum and the intussuscipiens. In actual fact an artificial line of cleavage was found by unwittingly separating the muscle coats of the appendix. Thereafter by squeezing on the intracæcal projection of the appendix an easy reduction of the intussusception was obtained. Appendicectomy was then carried out. This had to be done with clamps on account of the width of the appendix base, the cæcum being closed by a through-and-through running suture which was in turn invaginated by a seromuscular stitch. The wound was closed.

She made an uneventful recovery, being discharged on the fourteenth day.

THE SPECIMEN.—Before fixation the appendix was found to be 18 cm. long and 6¼ cm. in diameter at its widest point. It was comma-shaped, the spherical enlargement at its base being the portion which was intussuscepted into the cæcum, and which gave the widest diameter. The intussuscipiens had gripped the appendix just distal to this spherical enlargement to cause a relative constriction at this point, below which the appendix gradually increased in size. The base of the appendix was found to be sealed over by a thin imperforate diaphragm excluding the appendix from communication with the cæcum. Around the base of the specimen there was a cuff of the muscular layer of the appendix, which had been turned back in the process of reducing the intussusception. A diverticulum was found projecting into the mesoappendix. The vessels were tortuous and stood out prominently as they coursed along the appendix. This latter feature is a common finding in this condition and has been remarked on in almost every case. On opening into the specimen the lumen was found to be filled with a large amount of gelatinous, milky-white, mucinous material, while it was noted that the muscular wall was greatly hypertrophied.

In *Fig.* 31 the specimen is seen after the shrinking natural to the completion of the fixation process, and is lying beside a measuring rod. It has attached to it for comparison an average sized 12·5-cm. Spencer Wells forceps. *Fig.* 32 shows the specimen opened. *Fig.* 33 is a diagrammatic representation of the intussusception as it was found before reduction.

SUMMARY AND CONCLUSIONS

1. Seven specimens of simple intussusception of the appendix are described, illustrating partial and complete intussusception, one of the cases being a mucocele of the appendix.

2. Reference is made to a total of 82 cases of this condition, including a historical survey of the literature on the subject.

3. The aetiology is considered in detail, and a pathological classification is suggested.

4. From the clinical point of view the characteristic feature is the occurrence of very severe colic, with periods of complete remission between the colics. The value of careful X-ray examination is stressed, a barium enema having outlined the condition in several cases, though not in all of these was the correct diagnosis made.

5. Several possible lines of treatment are considered, suitable to the different types of intussusception encountered.

ACKNOWLEDGEMENTS

I have much pleasure in making grateful acknowledgement to the people who have assisted directly and indirectly in the preparation of this paper.

In particular, I should like to express my indebtedness to Mr. Roy F. Young for permission to publish the case of mucocele of the appendix and for his advice and helpful criticism; and also to Professor Illingworth for his guidance.

To Mr. W. Campbell, Mr. W. W. Galbraith, Mr. A. J. Hutton, and to Mr. M. White, for permission to publish their cases; also to Professor J. Shaw Dunn for allowing me free use of the specimens in the Pathology Department, Western Infirmary, Glasgow.

To Miss C. Brown Kelly for the trouble she has taken with the paintings.

To the Rankin Fund for the illustrations of the case of mucocele of the appendix.

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CALCULI IMPACTED IN THE LOWER FOURTH OF THE URETER: THEIR REMOVAL BY THE URETERIC CORKSCREW

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An annotation in *The Lancet* (1942) on "Removal of Ureteric Calculi by Traction" leads me to record a recent series of 20 cases in R.A.F. personnel in which perurethral traction methods were employed.

It seems to be generally accepted that it is impossible to grasp a stone impacted in the ureter by means of any type of cystoscopic forceps without at the same time running the risk of injury to a portion of the ureteric mucous membrane. Moreover, most observers agree that, in the majority of cases, it is a matter of great difficulty to pass a ureteric catheter beyond the stone, let alone to leave it in position and inject lubricants through it.

Finney's method of a looped ureteric catheter is based on a paper by Ludwig Zeiss (1937), an abstract of which by the present writer is to be found in the *British Journal of Urology* (1938), but it is not recommended owing to the difficulty of passing the catheter beyond the stone.

The procedure here described has been tried for some time, and consists of a combination of ureteric meatotomy and the use of the Welland-Howard spiral stone dislodger, modified to the author's design, and used as a ureteric corkscrew (*Fig.* 34). It is composed of a spiral wire ending in a small knob distally (*see Fig.* 47, B) to prevent laceration of the ureteric wall, and continuous with a long straight wire proximally, which passes through a stout ureteric catheter. The distal end of the wire is welded to a mount, which tops the catheter, and its proximal end to a milled thumb-screw to facilitate rotation. The instrument is twisted around the stone—this being at variance with the dictum of W. Bisher

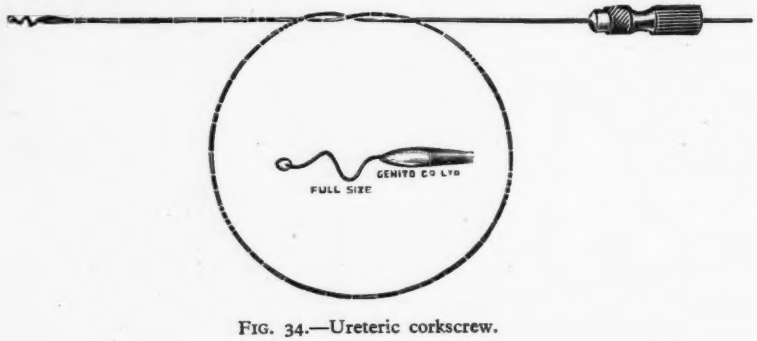

Fig. 34.—Ureteric corkscrew.

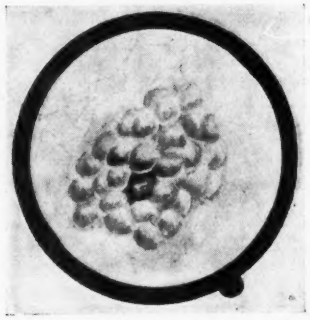

Fig. 35.—Calculus projecting from left ureteric orifice, surrounded by bullous œdema.

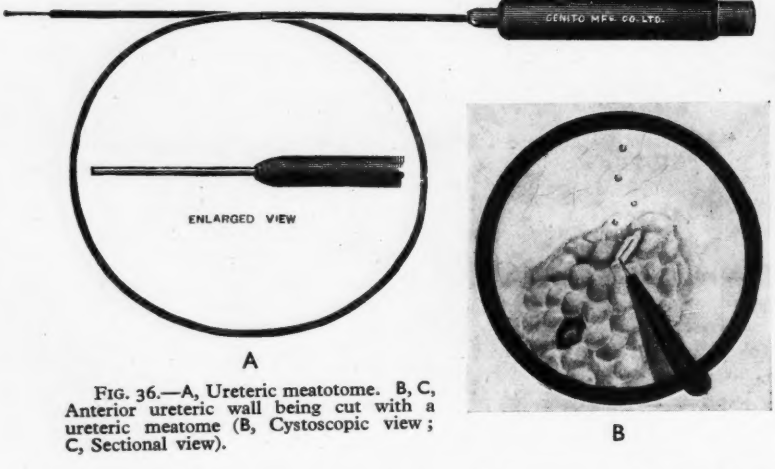

Fig. 36.—A, Ureteric meatotome. B, C, Anterior ureteric wall being cut with a ureteric meatome (B, Cystoscopic view; C, Sectional view).

(1937), who states that " although the extractor resembles a corkscrew, at no time in the entire procedure should it be twisted."

A large percentage of the smaller renal calculi, once they enter the ureter, will pass naturally without operative or instrumental interference,

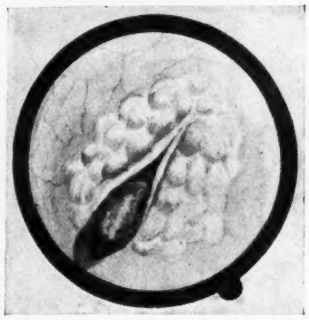

FIG. 37.—Calculus being ' born ' from left ureteric orifice.

though a number become impacted in either the upper or lower portion of the canal.

Those in the upper part should be removed by uretero-lithotomy if they give rise to back-pressure symptoms of renal pain, or to signs of dilatation of the renal pelvis and calices as shown by intravenous pyelography.

When the stone, however, is held up in the lower part of the ureter, instrumentation should invariably be given a trial before resort is made to operative measures. If the stone is actually in the intramural portion, as shown by swelling and bullous œdema of the ureteric orifice (*Fig.* 35), it is usually a simple matter to ensure its passage into the bladder within 24 to 48 hours by cutting the anterior ureteric wall overlying the calculus with a ureteric meatotome (*Figs.* 36, A, B, C) passed through a single catheterizing cystoscope, whereby all the tissues are divided until the stone is fully exposed. In a few cases the result is dramatic, and the stone can be seen being ' born ' within a few minutes of meatotomy (*Fig.* 37). Stones impacted in the last few inches of the ureter but above its intramural part (as shown by X-ray examination (*Fig.* 39) and the absence of pathological changes around the orifice) are those to which this article refers, and for which extraction by the ureteric corkscrew is recommended.

On the day of instrumentation the patient is again radiographed to ensure the presence and determine the position of the calculus.

Apparatus Required.—

1. Cutting current diathermy apparatus.
2. An operating irrigating cystoscope.
3. A knife-pattern ureteric meatotome (*Fig.* 38).
4. A choice of ureteric corkscrews.
5. An irrigating stand.

Anæsthesia.—Preferably pentothal followed by gas and oxygen.

Technique.—The patient is placed in the lithotomy position on a salt plate connected with one terminal of the diathermy machine. The

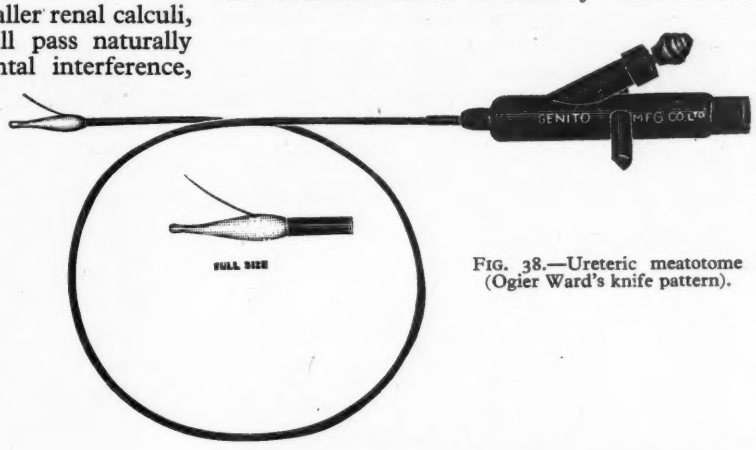

FIG. 38.—Ureteric meatotome (Ogier Ward's knife pattern).

cystoscope is passed, the obturator withdrawn, and the telescope, with single catheterizing attachment and meatotome, inserted. After connecting the latter to the other terminal of the diathermy machine, a survey of the bladder is made and the tip of the meatotome then inserted

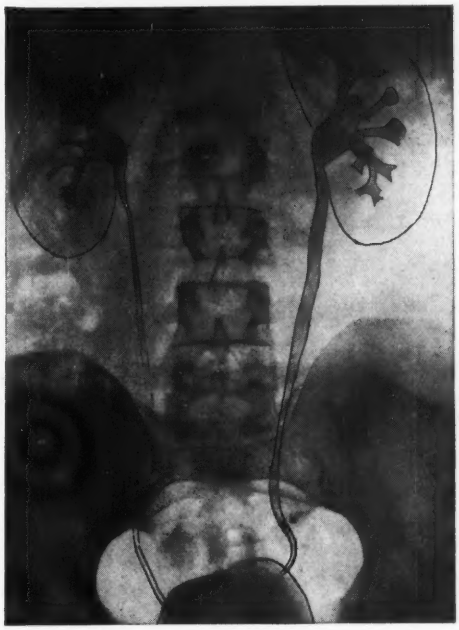

FIG. 39.—Calculus impacted in lower fourth of left ureter, with mild dilatation of calices, pelvis, and ureter.

into the obstructed ureter for a distance of 1·5 cm. great care being taken that the aperture of the diathermy knife is facing upwards and inwards, i.e., towards the bladder cavity. The knife is next made to present, by pressing the knob at the proximal end of the electrode, when a tent-like fold of anterior ureteric wall will be seen to be elevated (*Fig.* 40), and with a touch of the foot-switch the tip of the knife will emerge into the

bladder (*Fig.* 41). With the current on, gentle traction of the cystoscope will cause complete division of the wall of the ureter as far as its orifice (*Figs.* 42, 43), whereupon the knife is sheathed by pulling the knob of the meatotome and the latter withdrawn. In *Figs.* 40–42 the line of the intramural ureter has been deflected by the insertion of the meatotome, giving the impression that it is the right ureteric orifice which is being viewed. In *Fig.* 43 the ureter has resumed its normal direction and the orifice is obviously the left.

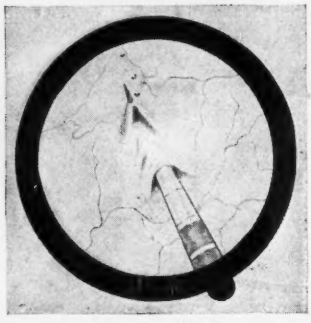

FIG. 40.—Elevation of tent-like fold of left anterior ureteric wall.

FIG. 41.—Knife emerging through left anterior ureteric wall.

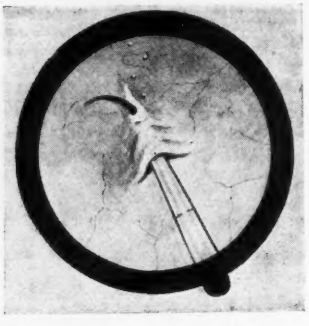

FIG. 42.—Meatotomy in progress.

FIG. 43.—Meatotomy completed; correct line of ureteric orifice restored.

A medium-sized ureteric corkscrew is passed through the catheter channel and its terminal button inserted into the enlarged ureteric orifice. By a process of gentle insertion and clockwise rotation it is made to traverse the lower end of the ureter until the obstruction caused by the calculus is encountered. Careful but persistent rotation is in most cases followed by a sudden cessation of resistance, which indicates that the corkscrew has passed beyond the stone (*Fig.* 44). It is then gently withdrawn *without* rotation until obstruction is again met with, when it can be assumed that the stone has engaged in the mesh of the spiral (*Fig.* 45).

Further withdrawal must be tempered with extreme caution, as this may result in laceration of the delicate ureteric mucous membrane by a spiculated calculus, although in some cases the stone can actually be pulled into the bladder in this way.

As a rule, however, it is wisest to empty the bladder and to withdraw the telescope, the catheterizing attachment, and cystoscopic sheath, thus leaving in situ only the ureteric corkscrew. The patient is then returned to the ward.

When recovery from the anæsthetic is complete, a further radiograph is taken to determine the relative positions of the calculus and of the corkscrew, and a small weight extension is applied to the distal end of the corkscrew by means of a pulley attached to a bed cradle. A string is provided whereby the patient himself can raise the weight and so remove its entire pull (*Fig.* 46) should the traction cause extreme discomfort. The corkscrew should be marked at its point of emergence from the urethra, so that the effect of the extension can be gauged.

In the majority of instances this method of gradual traction on the calculus will ensure its passage into the bladder, and, in a few cases, by adhering to the spiral, through the urethra as well.

If at the end of 48 hours there has been no appreciable movement of the corkscrew the patient is taken to the theatre and, under pentothal anæsthesia, an observation cystoscope is passed, and the bladder washed out and distended. Under direct vision the corkscrew is withdrawn

from the ureter into the bladder, together with the calculus, which by now will usually be found securely enmeshed. The bladder is emptied, the cystoscope removed, and the corkscrew pulled out, when, in some cases, the stone will be seen inside its spiral (*Fig.* 47, A) and in others be left in the bladder and passed naturally at a later date.

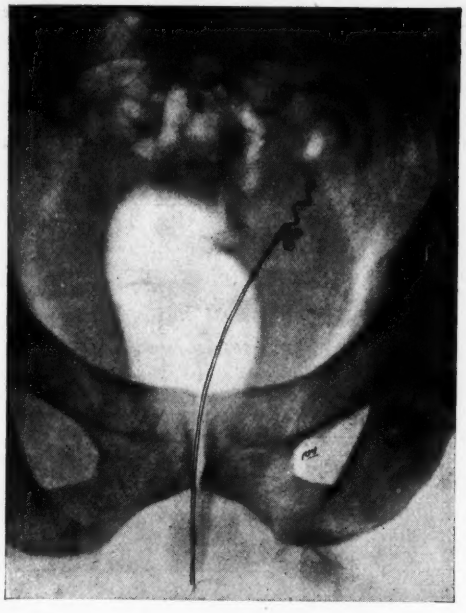

FIG. 44.—Ureteric corkscrew passed beyond calculus in left ureter.

Occasionally the procedures just described will cause the crumbling of the calculus, which is subsequently voided in the urine in small fragments—a less spectacular but equally satisfactory conclusion.

Routine urological investigation should in all cases be carried out after a period of one month, to establish the complete recovery of the affected half of the upper urinary tract and to discover, if possible, the original cause of the calculus so that this may be eradicated.

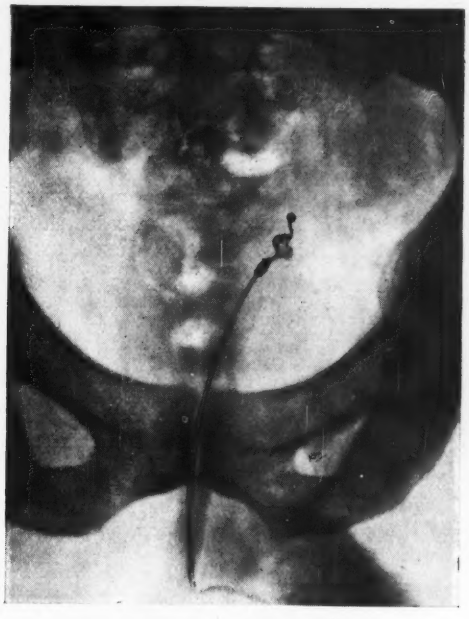

FIG. 45.—Ureteric corkscrew engaging with calculus in left ureter.

In a few cases all attempts to pass the corkscrew beyond the stone will fail. In the absence of back-pressure signs on the kidney, a further attempt should be made in a few weeks' time. Should pyelography, however, show dilatation of the renal pelvis and calices, uretero-lithotomy must be performed through a median suprapubic incision.

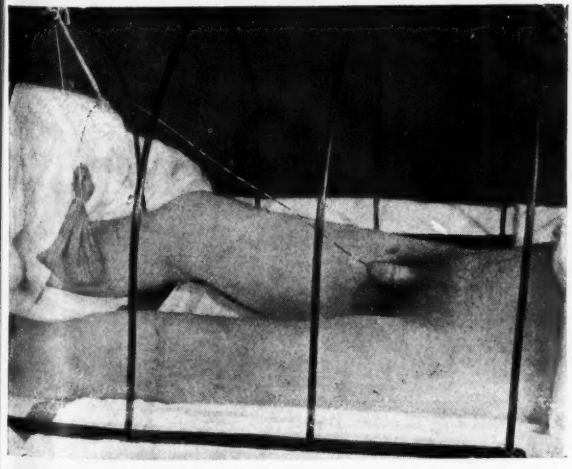

FIG. 46.—Weight extension applied to ureteric corkscrew after patient has returned to bed.

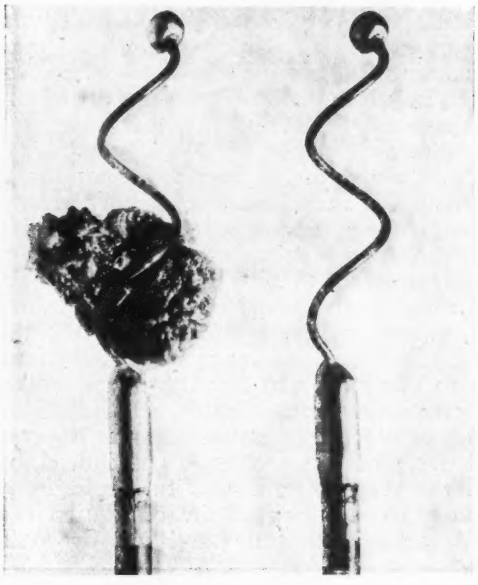

FIG. 47.—A, Calculus engaged in mesh of ureteric corkscrew after removal; B, Enlarged view of ureteric corkscrew.

After the successful passage of the corkscrew beyond the stone, its withdrawal may fail to engage the calculus, as shown by complete absence of resistance and the appearance of the spiral at the ureteric orifice. This indicates that the ureteric lumen is amply large and that the stone should pass naturally at a subsequent date —and indeed is more likely to do so from probable alteration of its position by the passage of the corkscrew and from enlargement of the ureteric orifice by the meatotomy.

Results.—The method of traction by the ureteric corkscrew has been used on 20 patients in the past twelve months; in all cases the stone was impacted in the lower part of the ureter above its intramural portion. In 2 cases the stone was removed at the time of the initial instrumentation; in 3, after forty-eight hours of weight extension; in 6 cases it was extracted after a second attempt; and in 8 the stone was passed naturally within three weeks of instrumentation. In the one unsuccessful case, two attempts to pass the corkscrew having failed, the stone was removed by operation.

My thanks are due to Blackwell Scientific Publications, Limited, for the loan of blocks for *Figs.* 35, 36, B, C, 37, 38, 40–47, and to Mr. Schranz of the Genito-Urinary Mfg. Co., for the loan of blocks for *Figs.* 34, 36 A, and 39, and who constructed, not only the ureteric corkscrews and the meatotomes, but also the operating irrigating cystoscope through which they were used.

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THE HISTORY OF BLOOD TRANSFUSION, 1628-1914*

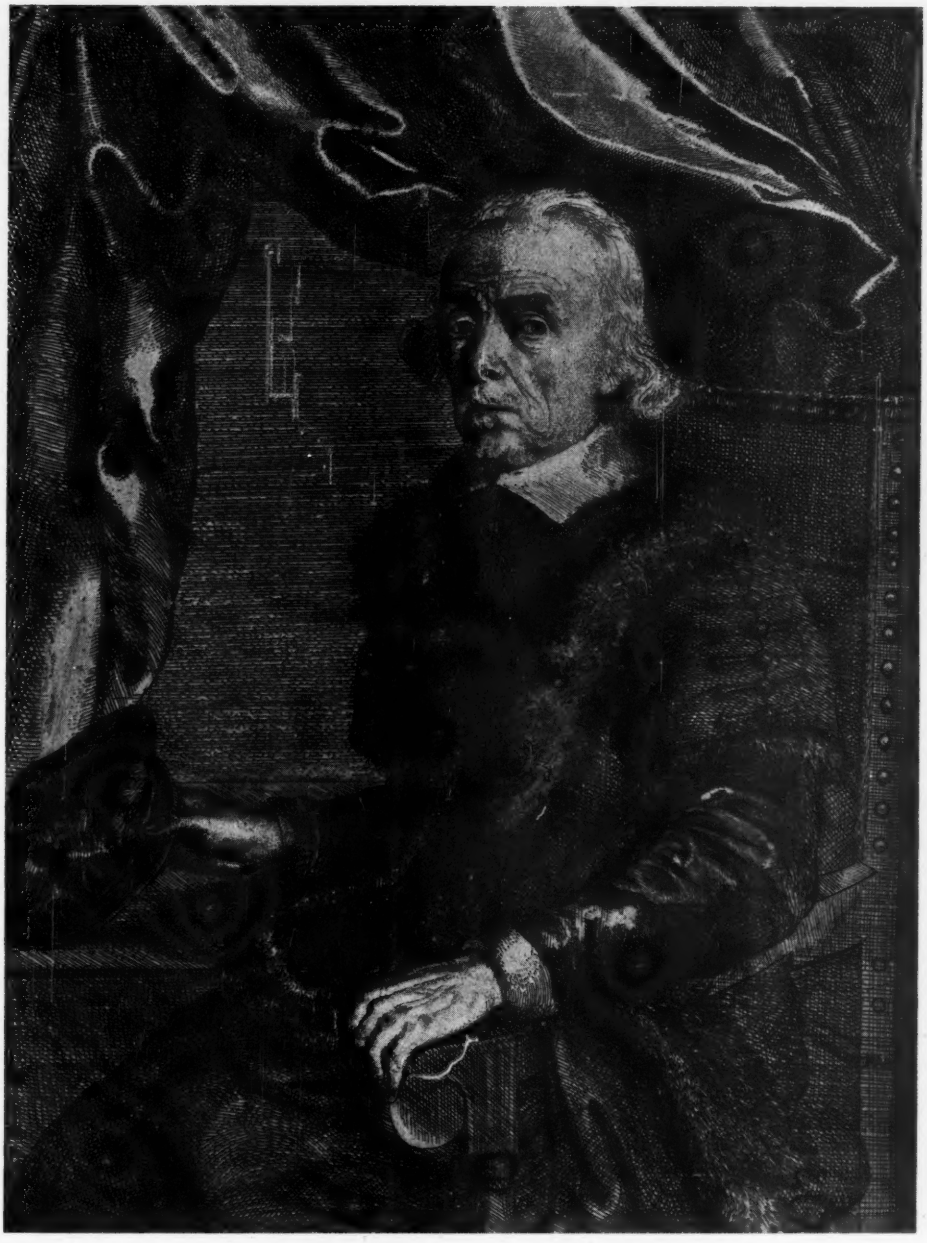
BY GEOFFREY KEYNES, LONDON

BLOOD transfusion for therapeutic purposes is now one of the commonplaces of medical practice. Yet it is less than twenty-five years since it came to be recognized as a practicable procedure of wide application, and it is of value to retrace in clear outlines the stages by which this immensely important advance came about; and to understand why its evolution was so slow, although its value in saving human life is now so obvious. In the present account particular attention will be given to the earlier efforts of our predecessors in medical science, interest being often stimulated more by knowledge of the work of pioneers and originators than by that of late-comers, even though it is commonly the refinements of knowledge and the perfections of practice that are the more difficult to achieve.

From the dawn of human history the vital importance of the blood in the animal economy has been fully appreciated, so much so that it was usually invested with many mysterious properties, and was supposed to carry with it the characters of its owners, both mental and physical. All the classical and medieval references to the therapeutic value of blood are more related to magic than to medicine, and this continued until well into the seventeenth century, so that the true history of blood transfusion does not begin until a relatively late date—it could not, indeed, begin until the minds of the medical profession had seized the conception of the circulation of the blood, enunciated and published by William Harvey in 1628. Although Harvey had himself pumped water through the circulation of a dead man,[13] there is no evidence that he ever considered blood transfusion in relation to his medical practice. In the same year, 1628, a Professor at Padua University, Johannes Colle, who may have known before of Harvey's work, did seriously suggest transfusion as a practical proposition, though he did not perform it. During the next twenty-five years the conception of the circulation was sinking in, but it was not until after 1655 that the scramble for priority can really be said to begin in relation to the practice of transfusion.

There were several phases to be gone through: (1) The formulation in men's minds of the *idea* of introducing other fluids and drugs in solution into the circulation of an animal; (2) The extension of the idea to include the introduction of blood; (3) The preliminary experiments on the circulating blood of animals; (4) The application of the results to the therapeutic use of blood transfusion in man. It was only to be expected that several minds in different countries of Europe should be thinking along parallel lines, and so giving rise to conflicting claims when it came to deciding the question of priorities. As an example of this process we may first examine the writings of a Florentine physician, Francesco Folli,[12] who published in 1680 a book setting out his claim to be the originator of blood transfusion. He stated that he read William Harvey's treatise on the motion of the heart in 1652, and thereupon formed in his mind the idea that transfusion of blood should be possible to cure diseases and to rejuvenate the aged. He recalled that he had seen

* A Friday evening discourse, delivered at the Royal Institution, April 9, 1943.



WILLIAM HARVEY, ATTRIBUTED TO HOLLAR.

(*From an impression formerly in the collection of Mr. W. B. Dukes.*)

Note on the Portrait

This etched portrait of Harvey has no special pretensions as a work of art, but it seems to be of great importance as a document, although it has been hitherto overlooked by all authorities on Harvey's life. The origin of the portrait is obscure. It may be confidently dated about 1650 when Harvey was aged 72, but the artist remains unknown. The copper-plate, which is unsigned, and measures 20·5 by 15·5 cm., has been attributed to Václav Hollar (1607–1677), the famous Czech master of etching, who spent most of his professional life in England, but the attribution is not admitted by any of the authorities on Hollar's work. Though the technique of the plate has much in common with his style and method, it is not regarded as being good enough to stand as wholly from his hand. Nevertheless, it cannot be denied that the representation of the face and hands gives a lively and convincing view of Harvey, more so, in the writer's opinion, than does any other extant portrait of the subject. The attribution of the plate to Hollar is particularly attractive because he and Harvey must have known one another intimately, having both been in the train of the Earl of Arundel during his travels on diplomatic missions in Europe in 1636. The liveliness of the portrait suggests an artist who knew Harvey well, but Hollar seldom made portrait plates at first hand. He was rather the draughtsman and technician who made etchings after paintings and drawings by other artists. Although the origin of this plate is unknown, it was clearly derived from the same source as the very inferior painting now in the National Portrait Gallery. This painting is so bad that it cannot possibly be regarded as the original of the plate, unless, perhaps, its present condition is the result of later over-painting. It is nevertheless given as the source of the etching in *The British Museum Catalogue of Engraved Portraits*, and the statement is repeated in Sir D'Arcy Power's *Portraits of Dr. William Harvey*, Oxford, 1913. The print is very uncommon and probably was never published. There are impressions in the British Museum and the Pepys Library at Cambridge, and there is said to have been one in a Hollar collection at Prague. The impression from which the present reproduction has been made was sold at Sotheby's in July, 1942, and is now the property of Dr. E. Weil, who has kindly supplied a photograph.

the precedent in 1645 when he observed in Pisa a double monster in the shape of male twins joined together by their livers and surrounding parts of their bodies. Only one of the twins was able to eat and drink, the other being in many ways imperfect, so that it was dependent for its

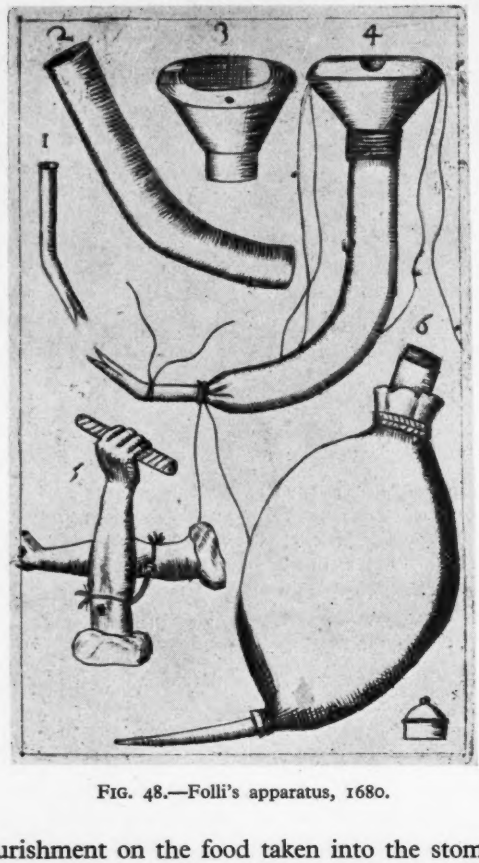


FIG. 48.—Folli's apparatus, 1680.

nourishment on the food taken into the stomach of its brother. Nature had thus provided an example of blood transfusion, one stomach nourishing two bodies through a common circulation. Harvey's treatise clinched the matter in Folli's mind, and he goes on: "This I pointed out in my pamphlet on life culture, which was published for no other reason but to make known to all that blood transfusion had been invented by me at the end of 1654 and demonstrated to his Serene Highness Ferdinand II, Grand Duke of Tuscany, of undying memory. The novelty of it had pleased him, or the fascinating ingenuity or the considerable experimental elaboration. To no one else did I impart my idea, believing that if such an invention were successful, Monarchs alone were worthy of it".

Later in the book Folli describes in some detail the apparatus required and the method of using it. He even postulates the presence of twenty young men as blood donors, so that the patient may receive every day the blood of a fresh donor over a considerable period. The illustration (*Fig.* 48) shows his apparatus consisting of a funnel connected by a tube formed from a goat's artery with a gold or silver cannula to be inserted in the patient's vein. It is all very ingenious, but near the end of the book comes the confession which spoils it all. "Finally", he says, "I know that I have said too much concerning the manner of carrying out the operation, not having made the experiment, . . . but I have done it solely so that every one, however simple and ignorant, could understand, be inspired, and even make the experiment with the least possible expense, and to this end only I have written in the vulgar tongue". Folli did, indeed, decorate his portrait in his book with the emblems of his supposed discovery, but it all existed only in his imagination and his claim to be a pioneer in the practice of blood transfusion can be firmly rejected.

Another more genuine, though pathetically unsuccessful, attempt at transfusion was made by the eccentric Vicar of Kilmanton in Somerset, Francis Potter. It is stated by Anthony Wood[30] that he had the idea of curing diseases by blood transfusion as early as 1640, but he chose the hen for his experiments. Later he wrote to John Aubrey[2] that "I am as yet frustrated *in ipso limine*, but it is by my owne unexpertnes, who never attempted any such thing upon any creature before: for I cannot, although I have tried divers times, strike the veine so as to make him bleed in any considerable quantity.

"I have prepared a little cleare transparent vessel (like unto a bladder) made of the craw of a pullet; and I have fastened an ivory pipe to one of the neckes of it, and I have put it into a veine which is most conspicuous about the lowest joint of the hinder legges; and yet I cannot procure above 2 or 3 drops of blood to come into the pipe or the bladder". This was written in December, 1652, but it cannot be claimed that the Reverend Francis Potter had greatly advanced the art of blood transfusion.

We may pass over other claims with equally, or even more, slender foundations, and turn to consider the more objective claims of the true originators of blood transfusion working in England and France. The first experiments are to be attributed to the ingenious mind and clever hands of Dr. (afterwards Sir Christopher) Wren. Dr. Thomas Sprat, in his *History of the Royal Society*, 1667, records that "he [Dr. Wren] was the first Author of the Noble Anatomical Experiment of Injecting Liquors into the Veins of Animals: An Experiment now vulgarly known; but long since exhibited to the Meetings at Oxford, and thence carried by some Germans, and publish'd abroad. By this Operation Creatures were immediately purg'd, vomited, intoxicated, kill'd, or reviv'd according to the quality of the Liquor injected. Hence arose many new Experiments, and chiefly that of Transfusing Blood, which the Society has prosecuted in sundry Instances, that will probably end in extraordinary Success". This was in 1657, and Wren's experiments were described by the great Robert Boyle in his *Usefulness of*

Experimental Philosophy published in 1663. The Royal Society had been started in London in 1661 and received its Royal Charter in 1662, and it was this " philosophic assembly " of distinguished scientists that witnessed the beginnings of blood transfusion. Among several persons concerned in the experiments, Richard Lower, then a doctor practising in Oxford, claims first place, though preliminary suggestions and experiments had been made by others. This is revealed by entries in the Journal Book of the Royal Society (quoted by Aveling[3]) :—

May 17, 1665. " It was suggested by Dr. Wilkins that the experiment of injecting the blood of one dog into the veins of another might be made ".

May 24, 1665. " Mr. Thos. Cox related that he had made an experiment of injecting the blood of one pigeon into the vein of another ".

May 31, 1665. " Dr. Croon suggested that a common pipe might be used for both, thereby to have the bloud of one dog suckt out by the other ". (This is the first mention of direct transfusion.)

June 7, 1665. " Dr. Wilkins reported that he by means of a small pipe of brass and a bladder injected two ounces of blood into the crural vein of a bitch ".

Robert Boyle had himself performed a similar operation, and on April 18, 1666, he declared that he thought Dr. Lower would be willing to prosecute the experiments at Oxford.

Lower's celebrated book[21] on the heart, published in 1669, proves him to have been one of the great pioneers in anatomy and physiology. In this book he states that he proposes " to reveal the conduct of the whole affair [of blood transfusion] and at the same time to show by what train of thought [he] first reasoned it out and undertook it, and, finally, by what means and aids it was carried into effect ". He goes on to say : " For many years at Oxford I saw others at work, and myself for the sake of experiment injected into the veins of living animals various opiate and emetic solutions, and many medicinal fluids of that sort. . . . But when, in addition, I likewise injected many nutrient solutions, and had seen the blood of different animals mix quite well and harmoniously with various injections of wine and beer, it soon occurred to me to try if the blood of different animals would not be much more suitable and would mix without danger or conflict. And because in shed blood . . . the natural blending and texture of the parts must of necessity change, I thought it much more convenient to transfer the unimpaired blood of an animal which was still alive and breathing into another. I thought this would be more easily effected, inasmuch as the movement of blood through its vessels is so rapid and swift, that I had observed almost the whole mass of blood flow out in a few seconds where an outlet offered. Taking hope from this, I turned mind and hands to put the matter to a practical test.

" And first I tried to transfer blood from the jugular vein of one animal to the jugular vein of a second by means of tubes between the two ; but, seeing the blood clot at once in the tube and block its own passage on account of the slow passage of the venous blood, I soon began to try another way, and guided, as it were, by nature herself, I finally determined to transfer blood from an artery of one animal into the vein of a second ; and by this new device to extend the circulation of the blood beyond the boundaries prescribed for it.

" As everything answered expectation as I wished, I finally showed this new experiment at Oxford towards the end of February, 1665 [1666 new style], in an interesting demonstration and under the most happy circumstances. . . .

" Having got ready the dogs, and made other preparations as required, I selected one dog of medium size, opened its jugular vein, and drew off blood, until it was quite clear from its howls and struggles that its strength was nearly gone and that convulsions were not far off. Then, to make up for the great loss of this dog by the blood of a second, I introduced blood from the cervical artery of a fairly large mastiff, which had been fastened alongside the first dog, until this latter by its restiveness showed in its turn that it was overfilled and burdened by the amount of the inflowing blood. This was repeated several times in succession, until there was no more blood or life left in two fairly large mastiffs. . . . In the meantime blood had been repeatedly withdrawn from this smaller animal and injected into it such amount as would equal, I imagine, the weight of its own body, yet, once its jugular vein was sewn up and its binding shackles cast off, it promptly jumped down from the table, and, apparently oblivious of its hurts, soon began to fondle its master, and to roll on the grass to clean itself of blood ; exactly as it would have done if it had merely been thrown into a stream, and with no more sign of discomfort or of displeasure ".

Lower's account of this is given at length because it is the first description of a successful direct transfusion from artery to vein, and so is of paramount importance in the present history. Lower illustrated his apparatus in an engraved plate (*Fig.* 49). He had at first used quills for uniting the blood-vessels of the two dogs, but afterwards decided that silver tubes could be more securely fixed in the emitting and receiving blood-vessels, these tubes being connected by a piece of the cervical artery taken from an ox. They were provided with small flanges so that they could be tied in more securely. The tube with a plate attached was devised for inserting into the arm vein of a human being.

These experiments were the subject of a series of letters between Lower and Boyle, and were described in No. 20 of the *Transactions* of the Royal Society, December 17, 1666.

Lower was at great pains to establish the facts of his experiments and their dates because, as he complained, " a certain Denis " was seeking to deprive him of priority in the matter and to

claim it for himself. This was Jean Denys, Professor of Philosophy and Mathematics at Montpellier, and physician to Louis XIV. Denys wrote a long letter from Paris in June, 1667, which was translated into English and actually printed as No. 27 of the *Transactions* of the Royal Society for July 22 of that year. It appears, however, that the printing was done without the knowledge of the Secretary, Henry Oldenburg, who happened to be in confinement in the Tower of London at the moment. Oldenburg was, however, released just in time to have the letter suppressed so that it is not included in most existing sets of the *Transactions*. It is now of great rarity.* Parts of it were published later. In this letter Denys describes his preliminary experiments on animals which were similar to Lower's, though certainly performed a year later, and explains how these led to a resolve to extend them to transfusing the blood of one kind of animal into the veins of another kind. In March, 1667, blood of a calf was therefore transfused into the veins of a dog, apparently without ill effect. Denys then argues at great length that it would be expedient to use the blood of an animal for treatment of disorders in man, and described how on June 15, 1667, he happened on a youth of 15 who had for months been tormented with a fever, for which he had been bled by his physicians twenty times " to assuage the excessive heat ". " Before this disease, he was not observed to be of a lumpish dull spirit, his memory was happy enough, and he seemed cheerful and nimble in body; but since the violence of his fever, his wit seem'd wholly sunk, his memory perfectly lost, and his body so heavy and drowsie that he was not fit for anything ". Accordingly he was bled to the extent of about 3 oz., and received in exchange about 9 oz. from the carotid artery of a lamb. The change that ensued was startling, and presently the boy was showing " a clear and smiling countenance " where previously he had passed the time " in an incredible stupidity ". He had felt " a very great heat along his arm ", which is the usual sign of an incompatible blood, but there were no further ill effects.

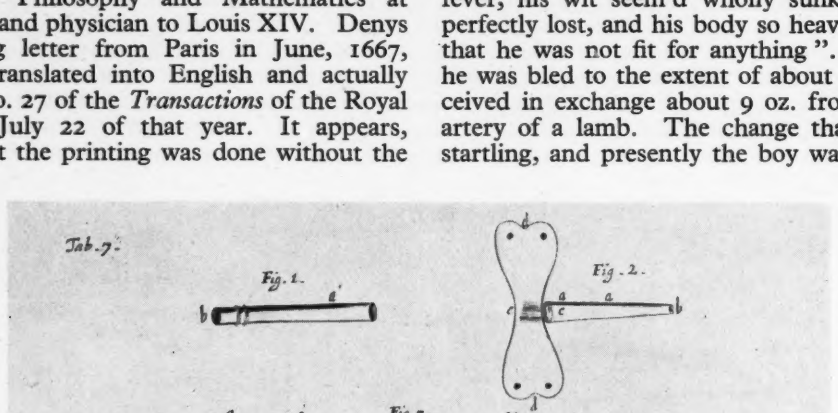


FIG. 49.—Lower's cannulæ, 1669.

This boy had been transfused for therapeutic purposes. Denys did his second transfusion upon an older man " having no considerable indisposition ", and it was purely experimental. The subject was supposed to have received about 20 oz. of lamb's blood, but again there were no ill effects, and it may be doubted whether the man received as much as this. Indeed " he abated nothing of his jovial humour " during the process, and when it was over zestfully cut the throat of the lamb and fleeced it, that having been his profession all his life! Denys afterwards performed further transfusions, and he claimed to have cured a patient suffering from " an inveterate phrenzy ". On this occasion the blood of a calf was used, and there can be no doubt that the patient received a considerable amount, for he showed all the signs of receiving incompatible blood—pain in the arm, a rapid and irregular pulse-rate, sweating, pain in his back, vomiting, and diarrhœa; he afterwards passed urine that was almost black with the hæmoglobin of destroyed blood-cells. In fact, he was fortunate to have escaped with his life.

* Copies are to be found in the library of the Royal Society, in Dr. John Fulton's library at Yale, and in my own.

Meanwhile in England the Royal Society circle had been working up to the point of transfusing a human being. Our best reporter is Samuel Pepys, who wrote in his Diary on November 14, 1666: "Here [at the Pope's Head] Dr. Croone told me, that, at the meeting at Gresham College tonight, . . . there was a pretty experiment of the blood of one dogg let out, till he died, into the body of another on one side, while all his own run out on the other side. The first died upon the place, and the other very well, and likely to do well. This did give occasion to many pretty wishes, as of the blood of a Quaker to be let into an Archbishop, and such like; but, as Dr. Croone says, may, if it takes, be of mighty use to man's health, for the amending of bad blood by borrowing from a better body". Other conversations followed, and a year later, under the date November 21, 1667, Pepys wrote: "Among the rest they discourse of a man that is a little frantic, that hath been a kind of minister, Dr. Wilkins saying that he hath read for him in his church, that is poor and a debauched man, that the College have hired for 20s. to have some of the blood of a sheep let into his body; and it is to be done on Saturday next. They purpose to let in about twelve ounces; which, they compute, is what will be let in in a minute's time by a watch. They differ in the opinion they have of the effects of it; some think it may have a good effect upon him as a frantic man by cooling his blood, others that it will not have any effect at all. But the man is a healthy man, and by this means will be able to give an account what alteration, if any, he do find in himself, and so may be usefull . . ." On November 30 Pepys dined at a house of entertainment, and enjoyed good company. "But here, above all, I was pleased to see the person who had his blood taken out. He speaks well, and did this day give the Society a relation thereof in Latin, saying that he finds himself much better since, and as a new man, but he is cracked a little in his head, though he speaks very reasonably and very well. He had but 20s. for his suffering it, and is to have the same again tried upon him: the first sound man that ever had it tried on him in England, and but one that we hear of in France, which was a porter hired by the virtuosos".

The subject of this experiment was one Arthur Coga, aged about 32, an indigent Bachelor of Divinity of Cambridge, and brother to the Master of Pembroke. It is recorded in the *Philosophical Transactions* that the experiment was performed by Drs. Richard Lower and Edmund King at Arundel House on November 23, 1667, that is, over six months after the first transfusion experiment on a human being had been done in Paris. It must be conceded, in fact, that, although Lower had the priority in animal to animal transfusion, Denys had the priority in animal to man. This cause for congratulation, however, did not last him for long, for in the next year, 1668, one of his patients died after the third of a series of transfusions, and the widow instituted proceedings against him. The case aroused great feeling, and ultimately a verdict was given against Denys. It was directed that in future no transfusion was to be performed without the permission of a member of the Faculty of Medicine of Paris. As the Faculty was bitterly opposed to the whole idea, this permission was never given, and in 1670 an Arrêt

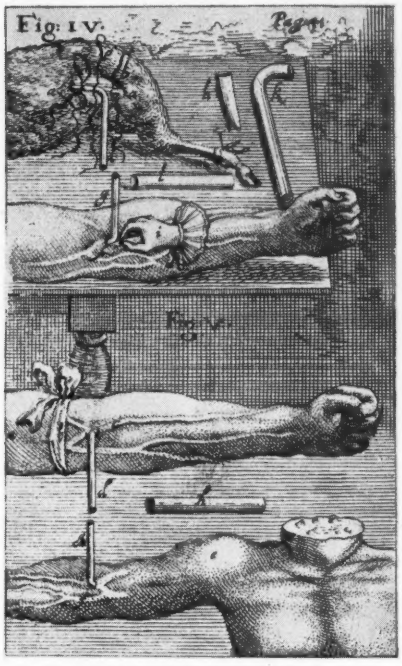


FIG. 50.—Elsholtz's figures, 1667.

forbade the practice of transfusion altogether.[23] The disaster which had overtaken Denys no doubt had its repercussions in London, and although the Journal Book of the Royal Society records that, as foretold by Pepys, Arthur Coga underwent a second transfusion without serious effect on December 14, 1667, this account was never published in the *Transactions*, perhaps because, as reported by Sir Philip Skippon in a letter to John Ray, "the effects of the transfusion are not seen, the coffee-houses having endeavoured to debauch the fellow, and so consequently discredit the Royal Society and make the experiment ridiculous".[25] Indeed, nothing more was heard of transfusions in England after a few further animal experiments had been done in 1669.

Nevertheless the noble experiment of transfusion in man had gained great notoriety, and some of the authors of text-books felt that they had to include an account of the procedure in their writings, though without inquiring too closely into the therapeutic results. One of the earliest illustrations (*Fig.* 50) was published by Elsholtz in his little book, *Clysmatica Nova*, in 1667.[11] He was very quick off the mark in giving an account of the experiments carried out in various countries.

Another illustration (*Fig.* 51) is taken from a standard text-book, the *Armamentarium Chirurgicum* of Scultetus, 1693.[26] It is evident that the picture was not taken from the life, but was, rather, a fanciful representation, idealized by the writer and his artist. The donor animal appears to be a dog, and the difficulties of the operation

FIG. 51.—Scultetus, transfusion, 1693.

are not indicated. In reality there must have been a good deal of mess. Still more fanciful is the representation (*Fig.* 52) given by Purmann in his surgical text-book published at Frankfurt in 1705.[24] Experiments had, of course, been done in Germany as well as in France and England, and the author had seen a transfusion done at Frankfurt in 1668, when a young man received lamb's blood with benefit. The Frankfurt lamb seems to be controlled almost solely by an admonishing finger, and no doubt Purmann's memory of the incident had again idealized the difficulties out of existence, though he does remark that usually transfusion helps but little.

Now that we know more of the grave dangers attending the transfusion of more than a small quantity of the blood of any animal into man we feel no surprise at the disrepute into which the operation fell after the year 1668. Animal blood, whether it be of dog, lamb, or calf, contains proteins which are totally incompatible with those in human blood. The transfused blood-cells are rapidly destroyed and the symptoms of anaphylaxis follow, causing the death of the patient if the amount of foreign protein introduced is large enough. Little, therefore, is to be recorded of blood transfusion throughout the eighteenth century, though towards its close, in 1794, the active mind of Dr. Erasmus Darwin was occupied with its possibilities. In his *Zoonomia*[9] he suggested blood transfusion for the treatment of putrid fever and cancer of the œsophagus, and for other conditions of impaired nutrition. He described the transference of blood from donor to recipient through goose quills connected by a short length of chicken's gut, which could be alternately allowed to fill from the donor and emptied by pressure into the patient. Again, however, this remained in the realm of good ideas, the operation never being actually performed. It was not until well into the nineteenth century that any serious revival of the operation was attempted.

We are now approaching the real crisis in the history of blood transfusion, the moment when the first transfusion in the modern sense was performed. During the seventeenth century there had been much playing with ideas, and in the earlier stages, as related, attempts had been made to use the blood of animals therapeutically, though usually, be it noted, to treat senility, insanity, or chronic diseases, rather than to meet the emergency of severe blood loss. Partly this may have been due to the difficulty of arranging an animal transfusion at short notice, but more, perhaps, to the preoccupation of the medical profession with the supposed mental or semi-magical effects of transfused blood rather than with its value in replacing blood that had been lost. The hero of this critical period was James Blundell, a noted physician, physiologist, and obstetrician, born in 1790. From 1814 to 1836 he was lecturer to Guy's and St. Thomas's Hospitals, and during this period he made notable contributions to abdominal surgery and to knowledge of blood transfusion. The *Dictionary of National Biography* records that he left at his

FIG. 52.—Purmann, transfusion, 1705.

death in 1877 a fortune of £350,000, but makes no reference to his work on transfusion. He was, nevertheless, a pioneer in this field, and he was stimulated to make his researches by realization of his helplessness in face of the severe and often

fatal hæmorrhages which might follow childbirth. As he rightly observed in 1834, " for the original operation the presence of some animal in the bed-chamber was necessary; what, then, was to be done in an emergency? A dog, it is true, might have come when you whistled, but the animal is small; a calf or a sheep might, to some, have appeared fitter for the purpose; but then it could not run upstairs. In this condition of it, the operation, little more than a name, was great in its danger, but of small advantage in those very cases of sudden bleeding in which it seemed most required ".[4]

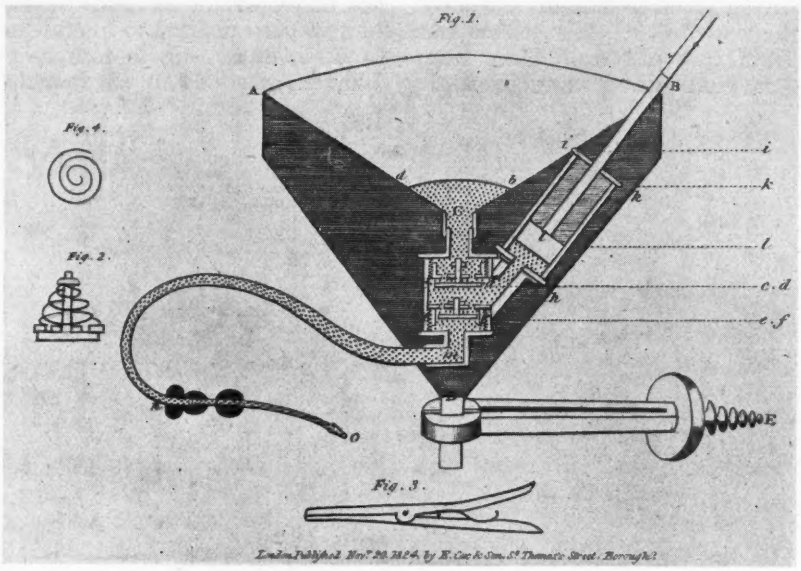


FIG. 53.—Blundell's impellor, 1824.

At the same time he was saved from making the bad initial error of his predecessors by the observation of a colleague, Dr. Leacock of Barbados, that the blood of animals might be harmful to human beings, or indeed that the blood of any one species might not serve for any other species. He therefore carried out a long series of experiments on dogs, showing firstly, like Lower before him, that an animal which had been bled almost to the point of death might be revived and restored to health by the blood of another dog, thus proving his initial contention that human lives might be saved by blood transfusion. He then showed that, if the exsanguinated dog were transfused with the blood of a sheep, it invariably died, even though there was a partial recovery at the start. These experiments sounded the warning against the transfusion of animal blood into human veins, and first established the modern doctrine of incompatibility of the bloods of different species.

The historic date to be assigned to the first transfusion of human blood is December 22, 1818, on which day Blundell read to the Medico-Chirurgical Society an account of the transfusion which he performed with the help of a celebrated surgeon, Henry Cline.[5] The patient was moribund from inanition due to obstruction of the outlet of the stomach. Blundell thought that he might benefit from a transfusion, and that in any event no harm would be done by the experiment.

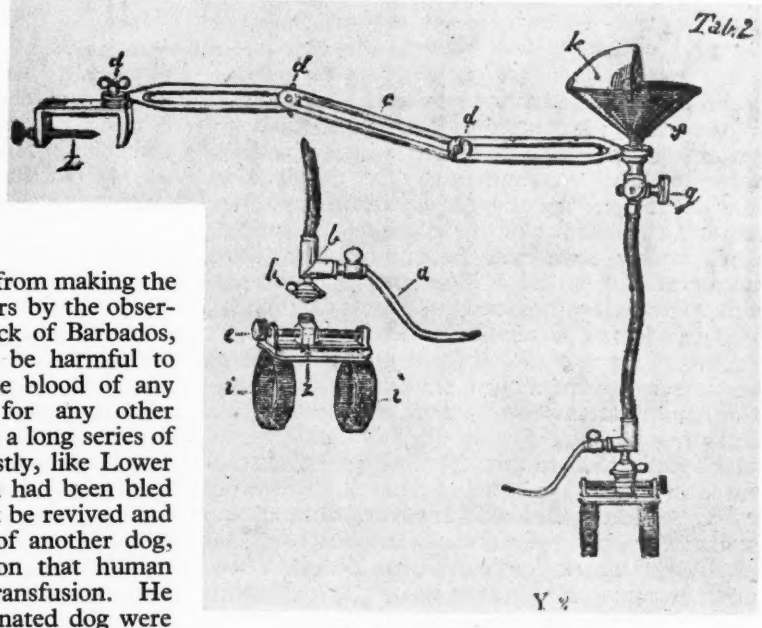


FIG. 54.—Blundell's gravitator, 1829.

The man received 12 to 14 oz. of blood from several donors by means of the syringe in the course of 30 to 40 minutes, and he temporarily improved, though he soon relapsed, and died 56 hours after the transfusion. His disease was incurable, and nothing could really have been expected from the transfusion, but evidently successful. Allowing for the two patients who were dead before he began, this means four successes out of eight attempts. Blundell was undoubtedly the first operator to transfuse human blood into human patients, and to him all honour is due.

It is interesting to make some note of how Blundell carried out his transfusions. At first

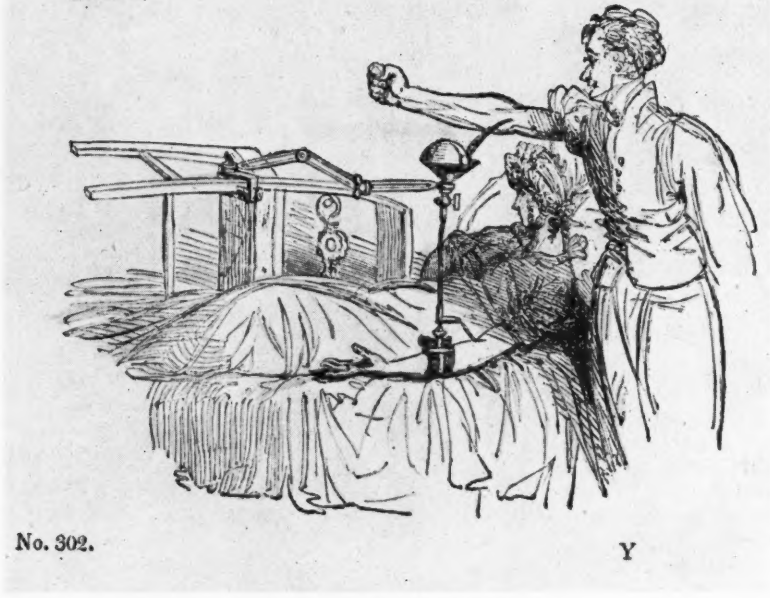


FIG. 55.—Blundell, transfusion, 1829.

Blundell was determined to start cautiously. When reading his paper he apologized for being prolix about a single operation, but justified the recording of every detail by the fact that it was a new departure. He was conscious, in fact, of the historic importance of the occasion, though he can scarcely have anticipated the time when transfusions were to be numbered by thousands and perhaps by millions. After 1818 Blundell performed more transfusions as occasion offered. In 1824[6] he recorded six operations, including the one already mentioned, chiefly for exsanguination, but his attempts were uniformly unsuccessful in saving life owing to the fact that at least two of his patients were already dead when he transfused them, and the remainder too ill for recovery to be possible. This was excessive caution, and statistically his operation failed, but he had established a precedent and a principle which was all-important. He persevered, and performed further transfusions. The record of a successful transfusion by Blundell is printed in *The Lancet* for 1829.[7] It was done for post-partum hæmorrhage, the patient receiving 8 oz. of blood from the arm of his assistant during the course of three hours, and making a good recovery. It is claimed for him that he performed ten transfusions in all, of which not more than four can have been he used a simple form of brass syringe and cannula, sucking blood out of the donor's vein and then injecting it into the patient's vein. But this did not satisfy him, so he invented a strange and clumsy-looking instrument called an "impellor", which was funnel and pump combined, as may be seen in the diagram (*Fig.* 53) published in his book of 1824. The outer compartment, shaded in the diagram, was filled with warm water. The donor's blood was made to flow into the funnel-shaped part above, and the action of the pump at one side forced the blood along the tube to the cannula inserted in the patient's vein by means of two oppositely-acting spring valves below the funnel. The impellor was fixed to the back of a chair to give it stability, and also to accommodate the blood-donor while blood was flowing from his arm into the funnel.

Later he invented another instrument, the gravitator (*Fig.* 54), in which gravity provided the motive force for pushing the blood into the patient's vein. This consisted of a funnel at the end of a long flexible bracket connected by a tube with a cannula which was buckled to the patient's arm. The other end of the bracket was again fixed to a chair (*Fig.* 55), but this time the blood donor had to stand, while he watched his blood gushing into the funnel.[8]

Blundell was at pains to show by experiment that the blood was not injured by its passage through an instrument, and that the introduction of a few air bubbles into the circulation was quite harmless. Earlier observers had thought that the smallest amount of air in the circulation was rapidly fatal. Blundell thus established so many fundamental points that it is difficult to exaggerate the importance of his work in the history of blood transfusion.

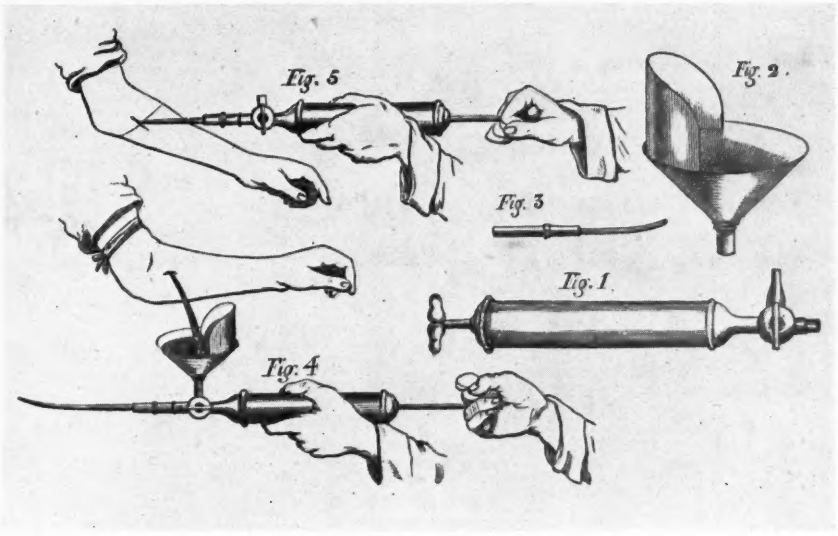


FIG. 56.—Waller's syringe, 1859.

Blundell also collaborated with two other experimenters, Doubleday and Waller,[10] who worked with a much larger animal, the horse. One of their experiments consisted in connecting the jugular vein of one animal with the carotid artery of another by means of a long elastic tube with a stop-cock at either end near the blood-vessels. One horse was then bled until it showed the signs of impending death—the stop-cocks were opened so that the blood flowed from the second horse into the first, which quickly recovered. This established, not only that recovery could take place after extreme exsanguination, but that a relatively small amount of blood was needed to effect it. For the second horse, so far from dying in saving the first with its blood, remained quite unconcerned, so that it was clearly unnecessary to replace the whole of the the blood that had been lost or anything approaching that quantity—a very important fact from the point of view of the human blood donor, who would not usually wish to risk his own life even if it were to save another. One of these experimenters, Dr. Charles Waller, himself practised blood transfusion to save women who bled in childbirth, and reported on instances of this in 1825 and 1826. He was writing about it again as late as 1859,[29] and then illustrated his method with a woodcut, showing a funnel, a 2-oz. syringe lined with tin, and a two-way tap connecting them with a cannula entering the patient's vein (*Fig.* 56). His patients in 1825 and 1826 received 4 and 8½ oz. of blood respectively given with the syringe, and the lady whose life he claimed to have saved in 1859 received 8 oz. These quantities would now be regarded as too small in view of the condition of exsanguination for which they were given. Doubleday, in 1825, gave as much as 14 oz., which was bold, particularly as his patient remarked after she had received only 6 oz.: "I am as strong as a bull". The effect was indeed strikingly satisfactory, the patient's pulse-rate falling within a short time from 140 to 104.

Other operators during the nineteenth century were employing other methods of transfusion, and one of the chief exponents of a more direct or immediate manner of transferring the blood was Dr. J. H. Aveling,[3] another obstetrician. He relates that he experimented in 1863 and as a result invented in 1873 the simple apparatus illustrated (*Fig.* 57). "It consists", he wrote, "of an indiarubber tube to form an anastomosis between the emittent and recipient veins and a little bulb in the middle to act as an auxiliary heart. With the exception of two silver tubes to enter the veins and two stop-cocks, this is the whole of the apparatus, and I carried it about in my pocket to every confinement I attended for eight years until at length the opportunity for using it arrived". This was in 1872 when he found a lady aged 21 *in extremis* from post-partum hæmorrhage. She received 60 drachms of blood from her coachman, and the incident is recorded in an admirable wood-cut (*Fig.* 58). She soon recovered enough to be able to remark that she was dying, though, Dr. Aveling added, "the mental improvement was not as marked and

rapid as I anticipated, but this was perhaps due to the quantity of brandy she had taken". The coachman, he was pleased to record, was not from the action of the living vessels for only a few seconds, and glides smoothly through the india-rubber pipe without being exposed to the air".

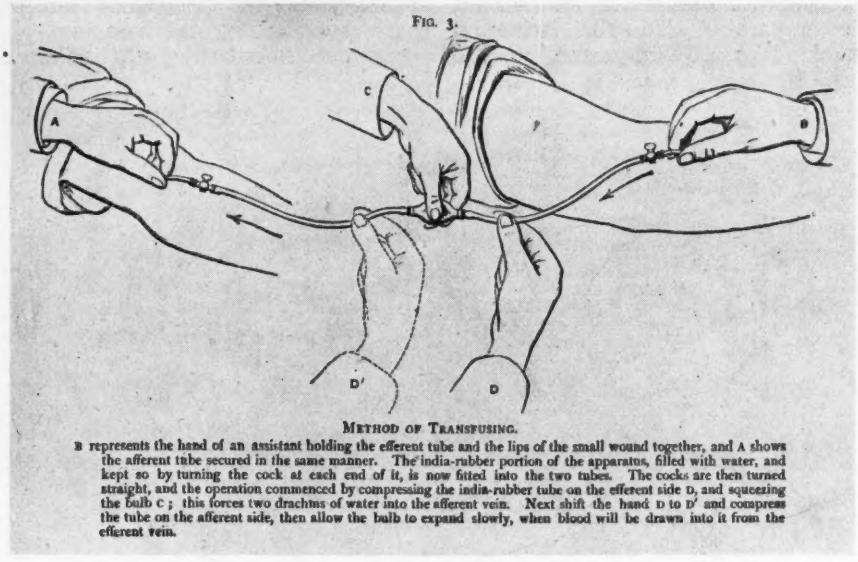


FIG. 3.
A
C
B
D'
D
METHOD OF TRANSFUSING.
B represents the hand of an assistant holding the efferent tube and the lips of the small wound together, and A shows the afferent tube secured in the same manner. The india-rubber portion of the apparatus, filled with water, and kept so by turning the cock at each end of it, is now fitted into the two tubes. The cocks are then turned straight, and the operation commenced by compressing the india-rubber tube on the efferent side D, and squeezing the bulb C; this forces two drachms of water into the afferent vein. Next shift the hand D to D' and compress the tube on the afferent side, then allow the bulb to expand slowly, when blood will be drawn into it from the efferent vein.

FIG. 57.—Aveling's method, 1873.

only collected and cheerful, but able to make several useful suggestions during the process of transfusion.

Aveling, after describing what he believes to be the only instances, seven in number, in which

All through the history of blood transfusion there was one main technical difficulty militating against the success of the operation, namely, the tendency of the blood to clot and so to block the tubes and other contrivances used in the

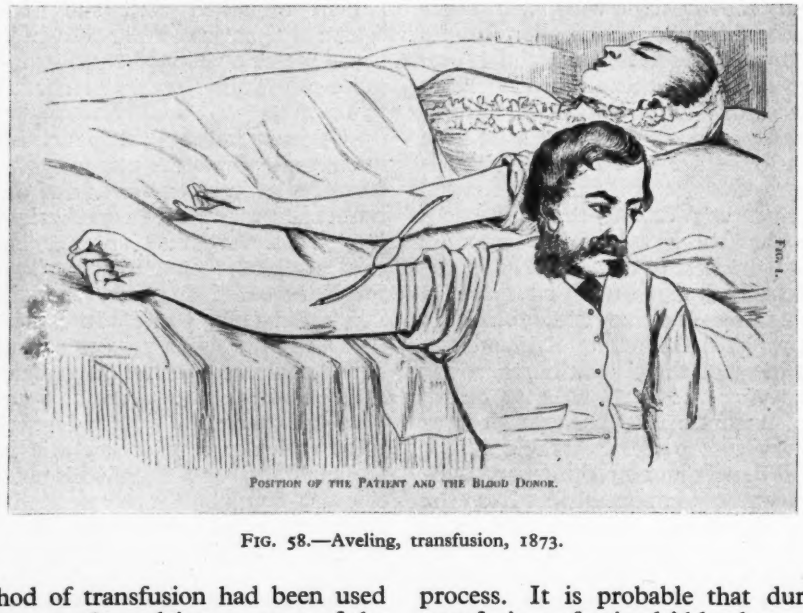


FIG. 58.—Aveling, transfusion, 1873.

the direct method of transfusion had been used in this country up to 1873, claims as some of the principal arguments in its favour that the blood passing quickly through the tube is physiologically unchanged, and that "the chances of coagulation are small, because the blood is removed

process. It is probable that during the earlier transfusions of animals' blood some of the patients owed their lives to the formation of clots, for had there not been this technical obstacle it seems certain that they would have received enough blood to kill them. As it was, a transfusion was to some

extent a self-limiting process, and once the value of the transfusion of human blood as a life-saving measure had been established, attempts to make it easier by preventing the clotting were bound to follow. One of the first to try this was Braxton Hicks, an obstetrician of Guy's Hospital. He was advised that phosphate of sodium was an effective anticoagulant, and in 1869 he described a series of transfusions given with the help of this reagent. In his paper[15] he first described attempts at transfusion in the old way. Thus in treating a woman for post-partum hæmorrhage he complains of various difficulties such as the faintness of the husband who was serving as donor. In addition to these complaints he goes on to say: "The apparatus employed was the funnel and syringe of Dr. Blundell [still in use after 45 years]. The coagulation of blood was the greatest trouble which interfered with the performance of the operation. The instrument had to be washed out three times, owing to coagulation during the check of the supply from faintness of the blood-giver, but I believe no clot was injected into the vein". Accordingly in 1863–4 he performed four transfusions using blood mixed with one-fourth its volume of a solution of sodium phosphate; unfortunately all the patients died, and the poisonous properties of sodium phosphate may have contributed to this result. An attempt, however, had been made in the right direction.

Considerable use was also made of defibrinated blood, that is to say, blood from which the clot has been removed. This method was employed in 1835 and later by many others including, in 1873, Sir Thomas Smith who used it at St. Bartholomew's Hospital for transfusing an infant suffering from hæmorrhage of the newborn.[28] His apparatus on this occasion included a wire egg-beater and a hair sieve with which to remove the clot. Defibrinated blood has been used up to recent times by various operators, but the process results in removal of a large part of the protein content of the blood and many of the cells, so that it is little better than a transfusion of serum besides adding much labour to the technique.

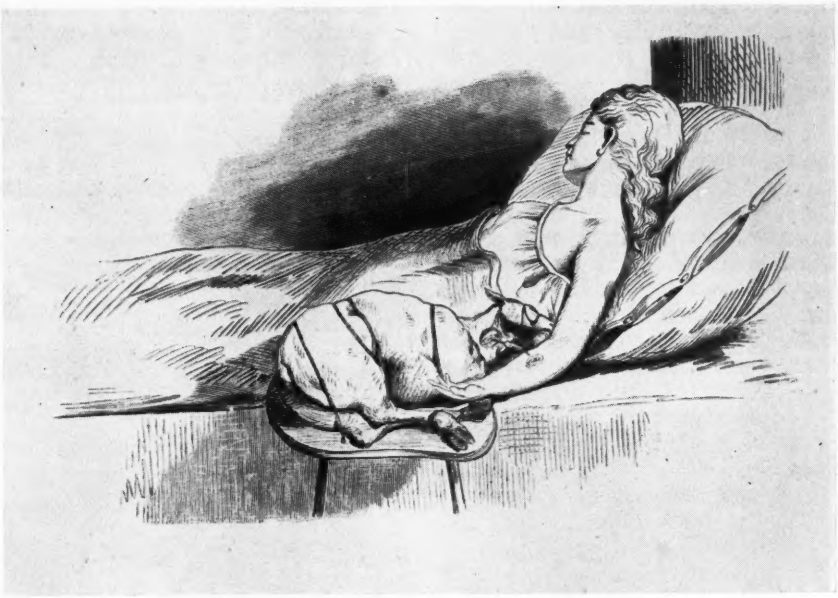


FIG. 59.—Hasse, transfusion, 1874.

Although so much of the early work on blood transfusion had been done in England, and although its revival in the nineteenth century was started in England, yet most of the references to it up to 1874 are to be found in the works of Continental writers. Nevertheless, an important modification was introduced into the technique of the operation in 1857 by Higginson,[16] who applied the principle of a rubber syringe with ball-valves for transferring the blood from the receptacle into which it was drawn to the vein of the patient. Higginson's syringe is now used for a different and less noble purpose, but it was successfully applied by its inventor in a series of seven transfusions which he duly reported. One patient was suffering from extreme weakness which was attributed to the too protracted suckling of twins. Higginson gave her about 12 oz. of blood from a healthy female servant, and a state of quietude followed her previous restlessness. A few minutes later the patient was seized with a rather severe rigor. It did not last long, but led to a state of reaction and excitement in which she sang a hymn in a loud voice. The final result was good and Higginson reported that some benefit was obtained from five of the seven transfusions.

Throughout the nineteenth century the main use of transfusion was in the practice of obstetrics, and in 1873 an inquiry was carried out by the Obstetrical Society of London into its merits. The result does not seem to have been very encouraging, and transfusion was still regarded as a procedure that was only to be used as a last resource. Even at this date there was an attempt in Germany to revive the use of lamb's blood and a treatise on the subject was published by Hasse,[14] who included an illustration (*Fig.* 59). Sentiment, if not science, seems to have suggested that there was something repulsive in bringing a lamb into the sick chamber and mixing animal with human blood, but it was remarked in a discussion on the subject that " it was only taking lamb in another form ".

Science, however, was taking note and was disturbed by the number of severe reactions and even deaths that followed transfusions not only of animal's, but also of human, blood. These effects were for long attributed to the introduction of air-bubbles into the circulation in spite of Blundell's demonstration of their harmlessness years before. Finally, however, in 1901, the presence of agglutinins and iso-agglutinins in the blood was detected by Landsteiner[19] and by Shattock[27] working independently in Vienna and London. In 1907 the four blood groups were determined by Jansky in Norway,[17] and the work was repeated by Moss at Baltimore in 1910.[22] This was an advance of fundamental importance since it now became possible to eliminate most of the fatalities due to incompatibility of blood. A test could rapidly be made to determine the blood groups of both donor and recipient.

In the years following this important discovery various improvements were made in the technique of transfusion. Direct transfusion from artery to vein was re-introduced and often used, though a serious objection to the method was the impossibility of knowing how much blood had really passed into the patient. Use was also made of the principle that clotting of blood is prevented or delayed by allowing it only to come into contact with surfaces coated with a smooth layer of paraffin wax. In 1913 the Kimpton-Brown[18] paraffined vessel was introduced, and this was used extensively in the United States of America.

The final advance was made in 1914 when the use of sodium citrate as an anticoagulant was made possible by the work of Lewisohn[20] in America and of several other workers in different countries, who all arrived independently at the same conclusion, thus again giving rise to rival claims of priority. It was proved that sodium citrate was at once effective as an anti-coagulant and also harmless in the quantity that was needed, and the first transfusion of citrated blood was performed by Professor Agote[1] of Buenos Ayres on November 14, 1914, a date which is, therefore, of the greatest importance in the history of transfusion. A method had at last been discovered which approached the ideal, since it united the four cardinal virtues of simplicity, certainty, safety, and efficiency. The " extraordinary success " predicted by Dr. Thomas Sprat in 1657 was now about to be realized, though there had been an unfortunate time-lag of 257 years.

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ABDOMINAL INJURIES DUE TO UNDER-WATER EXPLOSION

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ALTHOUGH considerable interest has been taken in blast injuries to the lungs, scanty information has come to light concerning injuries to the abdomen. From our experience there appears to be little difference in the abdominal cases whether the blast wave is air-borne or water-borne.

The modern depth charge produces a colossal pressure wave which has great destructive effects in its immediate neighbourhood (*Fig.* 60).

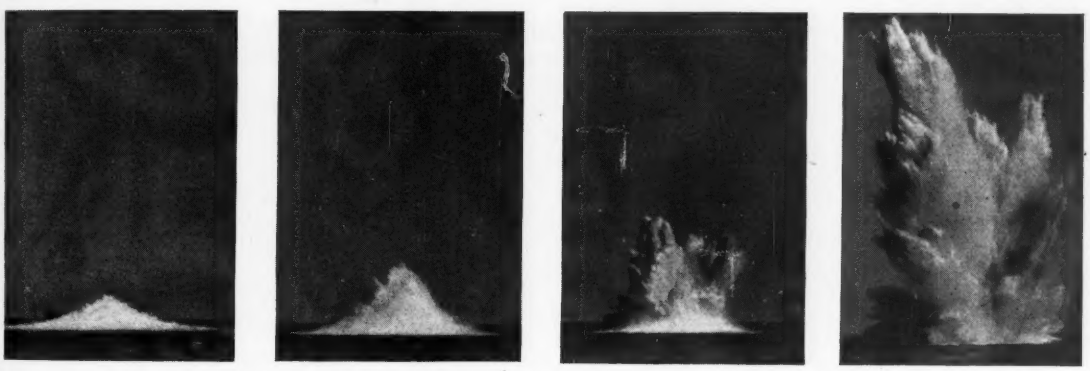


FIG. 60.—The explosion of a depth charge. Photographs taken at intervals of ¼ second.

In this article we are dealing only with abdominal injuries due to under-water explosions from depth charges, mines, bombs, and torpedoes.

A description of 20 cases which were subjected to operation will be given first, then an analysis of 80 cases, which, although severely shocked by such explosions, recovered without operation. Lastly, the results of experimental investigation will be discussed, as they throw considerable light on the probable way in which hæmorrhage and perforation may be produced by under-water explosions.

Although abdominal injuries due to under-water explosions were occasionally seen in the war of 1914–1918, yet very few cases were reported. One of us (C. P. G. W.) operated upon two cases in H.M.H.S. *Garth Castle* in 1918: One case, a stoker aged 21, sustained a rupture of his cæcum following the explosion of a mine two days prior to admission; he was suffering from diffuse peritonitis and operation failed to save his life. The second case was a boy aged 12 who was bathing off one of the Orkney Islands, when, owing to a rowing boat passing over them, a chain of mines was exploded in the vicinity. The boy was brought aboard the hospital ship some five hours after the explosion. He was very shocked and suffered from hæmoptysis and melæna. After being treated for shock his condition improved and no operative intervention was deemed necessary. However, twenty-four hours later he began to complain of his abdomen and it became evident that there was an acute abdominal condition. A laparotomy was performed and extensive retroperitoneal hæmorrhages were seen, and a rupture of the sigmoid colon was discovered. Simple suture reinforced with an omental graft was carried out under ether anæsthesia. The patient died the following day of bronchopneumonia. At autopsy there was some pelvic peritonitis, but the actual cause of death was an extensive bronchopneumonia and multiple hæmorrhages in the lungs. There can be no doubt on looking back on this case that the ether anæsthesia accelerated death in a patient who was suffering from ' blast lung '.

These two cases are of interest to-day because during the present campaign thousands of men have been subjected to blast from under-water explosions and the mortality has been very high. It is not possible to assess the figure as many are killed instantly or shortly after the explosion and their bodies are not recovered, or if recovered, rarely examined.

CLINICAL DATA

One of the commonest manifestations is the feeling of a sharp pain in the back at the moment of the explosion (Wakeley, 1943). Some patients describe this as a " sharp kick," others a " sudden electric shock ", while others liken it to a string tied round their waist and suddenly tightened. This symptom is probably due to spinal concussion and is often followed by paralysis of the legs which gradually passes off. Perhaps a description by an officer, after his ship was torpedoed one dark night in 1942, will illustrate this point. " On abandoning ship I swam away to windward to avoid as much oil fuel as possible. I had on a Service lifebelt blown up so that it was easily pressed in (from experience on *Ark Royal* I had found it was easily punctured if blown up too hard, by bumping into a sharp object in the dark). After approximately 20 minutes in the water, the ship having disappeared and whilst swimming around collecting the men into groups, there was a sudden explosion which I judged to be about 100 to 150 yards away. This, I thought to be a bomb, although no sound of aircraft was heard. It is hard to describe actually the effect it had on me, in medical terms, but it was just like a band being placed around my waist and being quickly tightened, together with a collapsed feeling as is felt after a sudden diarrhœa evacuation. I decided that if it was a bomb, more would follow, so attempted to turn over on to my back, but found that everything had gone numb from the waist down, and I could not raise my legs. This condition lasted for about an hour, then a tingling sensation like that of ' pins and needles ' set in until the movements of my legs became more or less normal again. I could not climb aboard the destroyer that picked me up, so was hauled up on a rope's end and helped down to the wardroom, but, thinking of the lads still left in the sea I went back on deck and did what I could to assist. The excitement probably took my thoughts off my own self, for I cannot remember feeling any further effects until after landing and going to bed at the hotel, when severe griping pains started, particularly on passing my motions. The bowels were open at least seven or eight times a day and it was then I first saw that blood of a normal colour was being passed. This continued for a week, but the slack motions and pain continued for a month before becoming less frequent. The explosion was definitely found to be an enemy torpedo which exploded at the end of its run."

This type of description is very common in the numerous histories given about the immediate effects of an under-water explosion.

Testicular pain is an accompaniment in a number of cases and has been commented upon by Breden, d'Abreu, and King (1942). There can be no doubt that this is due to small hæmorrhages underneath the tunica albuginea, and we have succeeded in producing such hæmorrhages experimentally. Vomiting is a very constant symptom, especially in those cases where a perforation has occurred. Oil fuel has been swallowed by a large number of patients and when this is vomited the medical attendant may be put off his guard and think that the oil fuel is responsible for the vomiting. The use of gastric ' suction ' via a Ryle or Miller-Abbott tube is of real value in these cases.

The clinical cases are difficult to classify, but it is fairly evident that water-blast lesions of the gut tend to occur in those parts of the alimentary tract that have a large amount of gaseous contents. Solid viscera are rarely injured and the liver was ruptured in only one of our cases. However, the liver is probably injured quite frequently in fatal cases, and more routine autopsies on such cases will settle this point.

The commonest lesions found at operation are retroperitoneal hæmorrhages, and these themselves may be so severe as actually to mask the picture of perforation. In none of the 20 cases recorded here was there any sign of external injury.

REPORTS OF 20 CASES SUBMITTED TO OPERATION

Case 1.—A stoker, aged 22, was in the water after his ship was torpedoed and was swimming towards a raft when an explosion occurred and he experienced

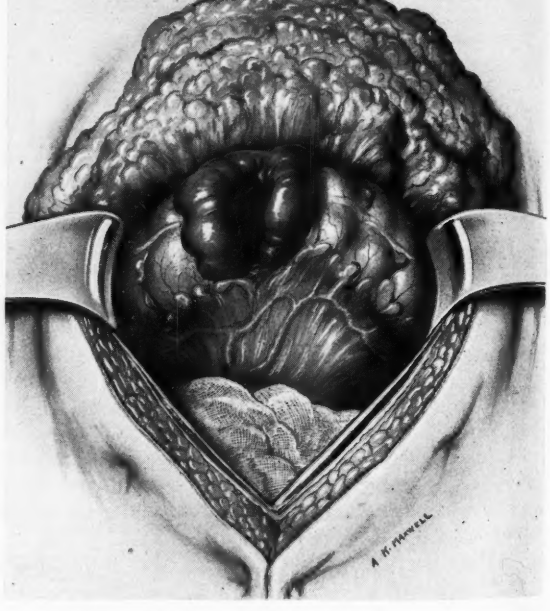


FIG. 61.—*Case* 1. Rupture of the transverse colon.

a sharp pain in the abdomen in the region of the umbilicus. His legs felt heavy, but he could still move them with difficulty. He was taken on board a coastal vessel and landed next day and taken to hospital. He vomited repeatedly and at times there was blood in his vomit. The abdomen was rigid and tender. On examination, twelve hours after the

injury, the patient had an anxious expression, rigid abdomen, and was continually vomiting; operation was decided upon. Laparotomy was performed by means of a right paramedian incision under gas and oxygen anæsthesia. On opening the abdomen, nothing abnormal was discovered except numerous retroperitoneal hæmorrhages. However, on raising the transverse colon a large perforation was seen (*Fig.* 61). The actual perforation was slit-like and situated at right angles to the long axis of the bowel. The mucous membrane was prolapsed and tended to close the aperture. A row of interrupted catgut sutures was inserted through the prolapsed mucous membrane, and this was reinforced by a continuous catgut suture. The omentum was sutured over the area by means of a few interrupted sutures. The abdomen was closed in layers without drainage. During the operation 500 c.c. of plasma and 250 c.c. of blood were given intravenously. The patient made an uneventful recovery and was discharged from hospital sixteen days after operation. This patient passed blood per anum for several days following operation, but the quantity on the whole was small.

There was no evidence of blast injury to the lung in this case from the clinical standpoint, although the patient was not X-rayed.

Case 2.—A sailor, aged 22, was in the sea following the destruction of his ship by means of enemy bombs. He was swimming towards another vessel when several depth charges exploded, his legs became paralysed and he became unconscious. However, his life jacket supported him and he was rescued soon afterwards and was transferred to hospital six hours after being injured.

His condition was one of severe shock and he was vomiting blood. Anti-shock measures were instituted and 800 c.c. of blood were given intravenously. After six hours in hospital his condition had improved somewhat, but abdominal pain and rigidity became more marked, although his pulse was only 80 and his blood-pressure 130/90. It was decided to await developments in this case and not to operate. For the next six hours the patient's condition improved, although his abdominal pain and rigidity remained. However, twenty-four hours after the injury he commenced to vomit almost continuously and the pulse-rate increased to 110. A right paramedian incision was used to expose the abdomen. On opening the peritoneal cavity blood-stained fluid escaped and later bowel contents with a distinct fæcal odour. There were several large retroperitoneal hæmorrhages and some subserous hæmorrhages scattered about on the gut wall. A perforation was found in the outer wall of the cæcum; this was closed by a double row of catgut Lembert sutures. The pelvic cavity contained a large collection of stinking pus and this was drained by means of a large drainage tube.

The patient was very shocked after the operation and died ten hours later. Post-mortem examination was not performed.

Case 3.—A deck hand, aged 19, was thrown into the sea when his ship hit a mine; the ship sank rapidly, and two or three depth charges exploded under the water as the ship sank. The man felt two or three sharp kicks in the abdomen and found that he could not use his legs; he was picked up quickly. His memory was poor for the sequence of events after the depth charges exploded.

He was admitted to hospital sixteen hours after the event in a very shocked condition. He was cold, sweating profusely, and coughing up blood, and he thought he was going to die. He was complaining of abdominal pain which seemed to be spasmodic in character. His abdomen was board-like, and he had definite signs of blast lung. He was warmed up, and given 500 c.c. of blood, but did not seem to improve, his condition slowly becoming worse, his pulse-rate mounting to 120. After five hours a further transfusion of 500 c.c. of blood was given and, as the clinical picture suggested a perforated viscus, a laparotomy was performed under local anæsthesia. On opening the abdomen, multiple perforations were found in the jejunum, ileum, and cæcum. These were all closed with interrupted catgut sutures. There were extensive retroperitoneal and subserous hæmorrhages. The condition of the patient did not warrant an extensive examination of the whole of the alimentary tract. The abdomen was closed without drainage. The patient died ten hours after operation and a post-mortem examination was refused.

Case 4.—A fireman, aged 42, found himself in the water after his tanker had hit a mine; he was swimming towards a rescue vessel when an under-water

FIG. 62.—*Case* 4. Two perforations on the outer wall of the cæcum.

explosion occurred and he felt acute pain in his belly and in his testicles. He estimated he was about a hundred yards away from the explosion. He discovered he could not move his legs and thought he was about to drown when he was picked up. After lying on the deck of a motor launch for half an hour he found he could move his legs again. He vomited four or five times during the next five hours but the vomit was not blood-stained. He was given a cigarette but he found smoking made him cough and he was surprised to find he coughed up some blood-stained sputum. He reached hospital twenty-six hours after his injury and was feeling quite fit. His abdominal pain had completely disappeared and his pulse and temperature were normal. After being in hospital three days and feeling quite well he was allowed to go on leave. The first three days on leave he felt quite well and except for a little abdominal discomfort, he thoroughly enjoyed himself with his family. On the eighth day after the injury he was

having breakfast when he suddenly complained of acute abdominal pain and vomited. When seen by his doctor two hours later he was sweating and in a very shocked condition. His abdomen was board-like and his condition was diagnosed as a perforated peptic ulcer and he was removed to hospital.

His condition improved somewhat while in hospital and the pain became most marked in the right iliac fossa, so the condition was then thought to be acute appendicitis.

Operation was decided upon and carried out four hours after reaching hospital. The abdomen was opened through a muscle-cutting incision in the right iliac fossa. There was some peritonitis and purulent fluid inside the abdomen. A normal appendix was seen lying over the pelvic brim (*Fig.* 62). The cæcum was thickened and rigid and on its outer wall were two perforations very similar in outline and characteristics to the perforations so commonly seen in a peptic ulcer. The outer and posterior wall of the cæcum was firmly adherent to the posterior abdominal wall. An attempt was made to obliterate the perforations by means of purse-string sutures but the wall of the cæcum was so thickened that this proved impossible. Both perforations were then covered by means of omental grafts. A drainage tube was inserted into the pelvic cavity and the abdominal wall was closed in layers. The patient's condition was never satisfactory after the operation, and he developed bronchitis the following day and died forty-eight hours after operation. Autopsy was not obtained.

Case 5.—A stoker, aged 23, was in the water after his ship had been torpedoed. He was swimming away from the ship when a depth charge exploded;

FIG. 63.—*Case* 5. Rupture of the small intestine due to water blast.

he felt a sudden pain in his belly in the region of the navel and experienced a sensation of 'pins and needles' in both legs, but he could still tread water. He managed to keep afloat for about a quarter of an hour when he was picked up and taken aboard a destroyer. He vomited soon after arriving on board and complained of abdominal pain. He was given ¼ gr. morphine and then he went to sleep on a stretcher. He arrived in hospital some sixteen hours after the injury and seemed quite comfortable, but his pulse-rate was 120 and his temperature was 100°. On examination of the abdomen there was definite tenderness in the region of the umbilicus with some well-marked rigidity. The patient was watched for six hours, during which time he vomited twice and the tenderness became more marked. It was decided to operate, and on opening the abdomen some free fluid escaped and a rupture of a loop of ileum was discovered (*Fig.* 63). There were few signs of peritoneal infection. The mucous membrane of the gut was considerably prolapsed through the opening and helped to prevent any extravasation of the intestinal contents. The perforation was closed with a double layer of interrupted Lembert sutures, and an omental graft was stitched over the area. The abdomen was closed without drainage.

The patient was nursed in Fowler's position and made an uninterrupted recovery.

Case 6.—A sailor, aged 19, was flung into the water when a torpedo hit his ship; he had just reached the surface when another torpedo made a direct hit and he experienced a sudden pain in his abdomen and promptly vomited. The ship sank rapidly and he was nearly drowned, being almost sucked under as the ship went down. He had difficulty in using his legs but he was not paralysed according to his own account of his symptoms. He was picked up within half an hour of the explosions and taken aboard a patrol boat. After some ten hours he was admitted to hospital in a rather shocked state. However, he soon responded well to anti-shock measures and slept for some six hours. Although his general condition was good he complained of abdominal pain and tenderness, especially in the right iliac fossa. The pulse-rate began to rise and he vomited several times. It was decided to operate and explore the abdomen. Laparotomy was performed through a right paramedian incision. Extensive retroperitoneal hæmorrhages were seen and a small tear perforation was found on the outer side of the cæcum. The rent was closed with a double row of interrupted sutures and an omental flap was stitched over the suture line. The abdomen was closed in layers, no drainage being employed. The patient made a rapid recovery in spite of some troublesome bronchitis.

Case 7.—A sailor, aged 24, was swimming away from his sinking ship when a series of under-water explosions occurred one after the other. At each explosion he experienced pain in the belly and in his testicles; he also lost the use of his legs. His lifebelt kept him afloat and he was picked up soon afterwards and taken aboard a destroyer. When he was examined he was very shocked and was vomiting continuously. He was given ⅓ gr. morphine and made comfortable on a stretcher. As he became warmer he felt 'pins and needles' in his legs; this sensation gradually disappeared and he found he could move his legs once more. He was admitted to hospital eight hours after the injury. He was still shocked, but he responded to warmth and intravenous plasma. On examination of the abdomen there was generalized tenderness and rigidity, which became more marked after four hours in hospital. His pulse-rate was 110 and his temperature 99·8°. His abdomen became distended and the vomiting continued. He had all the signs of peritonitis and operation was performed some fourteen hours after the injury.

On opening the abdomen, blood and intestinal contents escaped and there was a decided fæcal odour. There were many large retroperitoneal hæmorrhages and several subserous ones. Three perforations were found in the last four feet of the ileum, two were found in the jejunum, and a large

perforation was seen in the outer wall of the cæcum. The condition of the patient was poor and 1500 c.c. of blood were given intravenously during the operation. The perforations were quickly sutured with interrupted sutures and the abdomen closed in layers after the suture lines had been freely dusted with sulphanilamide powder. No drainage was employed. The patient never recovered from the operation and died eight hours later. No autopsy was performed.

Case 8.—A deck hand, aged 20, found himself in the water after his ship had been hit by a torpedo. After about a quarter of an hour the ship sank and

FIG. 64.—*Case* 8. Blast injury to the duodenum.

while he was clinging to the edge of a small raft an under-water explosion occurred and he experienced a sharp pain in his belly which he likened to a heavy kick, and he also felt some pain in his testicles. He was eventually pulled on to the raft and was picked up by a trawler some three hours later. He arrived in hospital eight hours after the injury. On examination in hospital there were few physical signs. The abdomen was somewhat guarded, but there was no actual rigidity or tenderness. The temperature and pulse were normal. The patient slept for ten hours, and on waking complained of abdominal pain and vomited. On examination there was distinct tenderness in the upper abdomen and some rigidity. The pain and vomiting persisted, so operation was decided upon. Laparotomy was performed twenty-two hours after the injury. A right paramedian incision was used and the peritoneal cavity exposed. A slit perforation was found in the first part of the duodenum (*Fig.* 64). There were many small retroperitoneal hæmorrhages scattered about on the posterior abdominal wall, and there was slight extravasation from the opening. The perforation was closed by means of a layer of interrupted sutures and a small omental graft was stitched over them. The abdomen was closed in layers without drainage. The patient made a straightforward recovery and was discharged from hospital on the sixteenth post-operative day.

Case 9.—An A.B., aged 21, was blasted off the deck of his destroyer when it hit a mine. He was swimming about in the water with some other ratings when the ship sank. A few minutes after the sinking of the ship two violent under-water explosions occurred in quick succession, causing acute abdominal pain as if he were being compressed against a wall. He found he could swim gently, but any violent effort caused further abdominal pain. He was picked up after three-quarters of an hour and taken back to port in a corvette. He was admitted to hospital some eight hours after his injury. On examination the patient was found to be somewhat shocked and exhausted, but he responded well to anti-shock treatment. Three hours later vomiting commenced and continued for three hours. The abdomen was rigid, especially so in the right iliac fossa, and all the symptoms of acute appendicitis were present. It was thought he might have a perforation of his cæcum so operation was decided upon. The abdomen was opened through a right paramedian incision. Some subserous and retroperitoneal hæmorrhages were seen, and a slit perforation on the outer wall of the cæcum was discovered. This was repaired by a double layer of interrupted sutures and the area dusted with sulphanilamide powder. The abdominal wound was closed without drainage. A blood transfusion of 500 c.c. was given during the operation.

The patient made a rapid and uneventful recovery. Some dark blood was passed per rectum on the third post-operative day, but this bleeding cleared up rapidly.

Case 10.—A stoker, aged 28, found himself in the sea after his ship had been hit by a mine. He remembered very little about the actual explosion, but was quite sure that after his ship had disappeared an under-water disturbance occurred which caused him some abdominal pain. He described the pain as "a firm slap on the belly." He was picked up and reached hospital ten hours later. On examination he was found to have a rigid abdomen with slight tenderness in the region of the umbilicus. The temperature and pulse-rates were normal. After an hour the patient vomited and the abdominal pain became more persistent. Laparotomy was performed eighteen hours after his injury. There were many scattered subserous and retroperitoneal hæmorrhages to be seen (*Fig.* 65), but no abnormality was found anywhere. The abdomen was closed without drainage.

The patient made an uneventful recovery and was discharged from hospital sixteen days later.

Case 11.—A deck hand, aged 23, had been in the water for about half an hour after his ship had sunk following enemy action from bombs, when another ship, about half a mile away, was hit by torpedo and the effect of the explosion was felt by the patient, who compared it to a "kick in the stomach". He felt sick and vomited once. He found he could not move his legs and would have drowned had it not been for his life-jacket. After about half an hour he began to experience a sensation of 'pins and needles' in his legs and found that he could move them again. Shortly after this he was picked up and arrived in

hospital eight hours after the injury. He was shocked and complained of abdominal pain. Anti-shock measures did not produce much improvement, and his pulse-rate rose steadily until it was 120 three hours after admission. Abdominal tenderness was general and there was rigidity all over the right abdominal quadrants. The respiration-rate was 24, and there was some difficulty in breathing. A radiograph with a portable apparatus revealed some blast effects in both lungs.

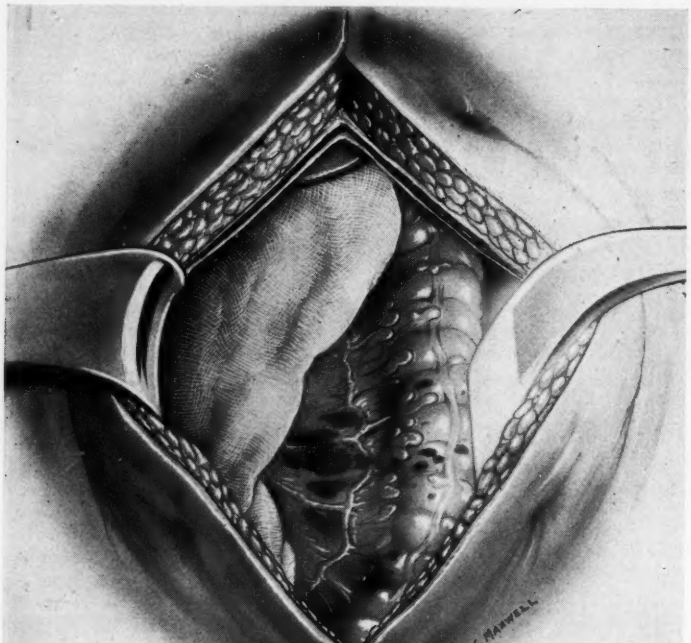


FIG. 65.—*Case* 10. Retroperitoneal hæmorrhages due to blast. The signs in this case were those of acute peritonitis. Laparotomy revealed only retroperitoneal hæmorrhages.

A blood transfusion of 600 c.c. was given and the abdomen opened sixteen hours after the injury. Local anæsthesia was used as the patient was having oxygen through a B.L.B. apparatus. On opening the abdomen much blood welled up and several lacerations were seen at the lower margin of the liver (*Fig.* 66). An attempt was made to suture some of these, but this proved unsuccessful as the suture cut through the liver substance. Small flaps of muscle were then taken from the rectus muscle and these were traumatized and packed into the liver lacerations. Hæmorrhage was completely controlled by this means. An examination of the rest of the abdominal cavity failed to reveal any other lesion. The abdomen was closed without drainage. Recovery was complete and uneventful and the patient left hospital eighteen days later.

Case 12.—A trimmer, aged 22, who found himself in the sea after his ship had been torpedoed, was swimming about with four other men when several under-water explosions occurred. These were probably depth charges dropped from a nearby destroyer in an attempt to destroy the enemy submarine that had been responsible for sinking the ship. The patient was almost upright in the water at the time of the explosions as he was "treading water". He experienced pain in his belly, testicles, and rectum, and vomited several times. He found that he could not move his legs, and two of his companions complained of similar symptoms. As far as he could judge, he was in the water for nearly an hour before he was rescued; he was, however, able to move his legs before this. He was taken aboard a destroyer and transferred to hospital some ten hours after the injury.

On examination there were definite signs of blast lung and the patient was coughing up blood-stained sputum. The abdomen was very rigid and tender and the patient had an anxious expression and was suffering from shock. The pulse was 120, temperature 98°, and respiration-rate 28. Anti-shock measures were adopted and 600 c.c. of blood were given intravenously.

The condition of the patient improved, but vomiting continued and the abdominal rigidity became 'board-like'. Twenty hours after the injury it was decided to operate, making use of intravenous anæsthesia.

The abdomen was opened through a right paramedian incision. The peritoneal cavity contained a little bloodstained fluid and large subserous and retroperitoneal hæmorrhages were numerous. A perforation was discovered on the outer wall of the cæcum (*Fig.* 67) and this was closed with interrupted sutures. No other injury or perforation was noticed. The abdomen was closed without drainage. A further 800 c.c. of blood were given during the operation.

The patient was in a better condition after the operation than he was before. The next day, however, he began to deteriorate and rapidly went

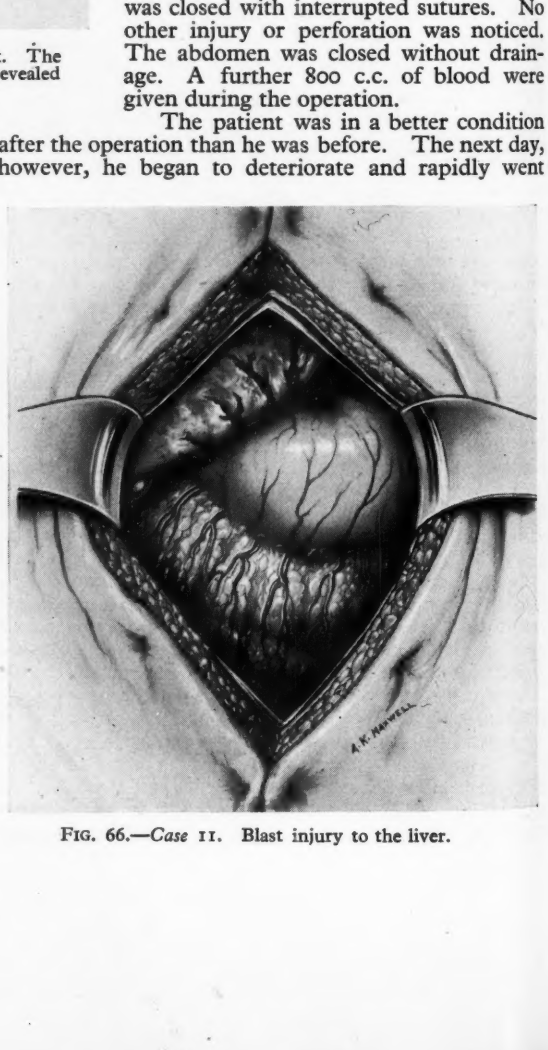


FIG. 66.—*Case* 11. Blast injury to the liver.

downhill and died forty-seven hours after his injury. No post-mortem examination was made.

FIG. 67.—*Case* 12. Blast injury to the cæcum. Multiple retroperitoneal hæmorrhages.

Case 13.—A sailor, aged 24, was a member of the same crew as *Case* 12, and was exposed to the same under-water explosions. He complained of abdominal pain immediately afterwards, but he did not vomit nor were his legs paralysed. After he was picked up he helped with some of the wounded men who were aboard the destroyer and when admitted to hospital his condition appeared more or less normal. The following day he wanted to get up, but this was not allowed. A radiograph of his chest did not reveal any blast changes and as he felt quite well he was allowed up on the third day. His bowels acted normally; also, as he was very hungry, he was on full diet by the fourth day in hospital. His clinical condition was so good after a week in hospital that he was allowed to go home on sick leave. While on leave on the tenth day after the injury he was suddenly seized with acute abdominal pain and vomiting. He was transferred to hospital and on admission he had all the signs and symptoms of a perforated peptic ulcer. He was sweating profusely and kept his knees drawn up almost on his abdomen. His abdomen was very rigid and tender. After three hours in hospital his condition was somewhat improved, but the abdominal pain and rigidity persisted. Laparotomy was performed under gas and oxygen anæsthesia. On opening the abdomen, some gas and free fluid escaped. A loop of terminal ileum was delivered out of the pelvis and a 'punched-out' perforation was seen (*Fig.* 68). Suture of this perforation proved to be difficult as the tissue round the perforation was very fibrotic. However, invagination by means of a purse-string suture was eventually performed. No other perforation was discovered and the abdomen was closed without drainage. A blood transfusion of 800 c.c. was given but the patient never showed any signs of recovery and died ten hours after the operation. No post-mortem examination was performed.

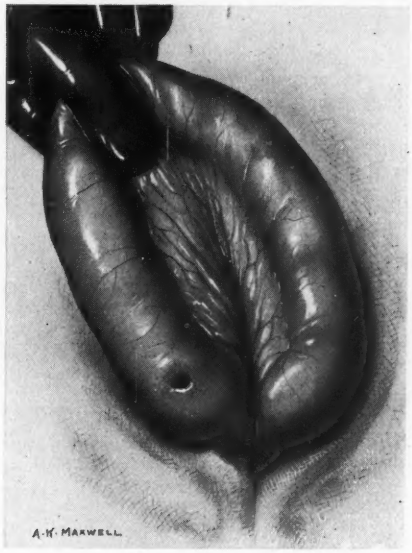


FIG. 68.—*Case* 13. A 'punched-out' perforation of the ileum.

Case 14.—A sailor, aged 30, dived into the sea when his ship hit a mine; he had just reached the surface of the water when an explosion occurred as the ship sank. He noticed a sudden pressure on his abdomen but it rapidly passed off and he forgot about it in the excitement of being rescued. He was taken on board a patrol boat and given a hot

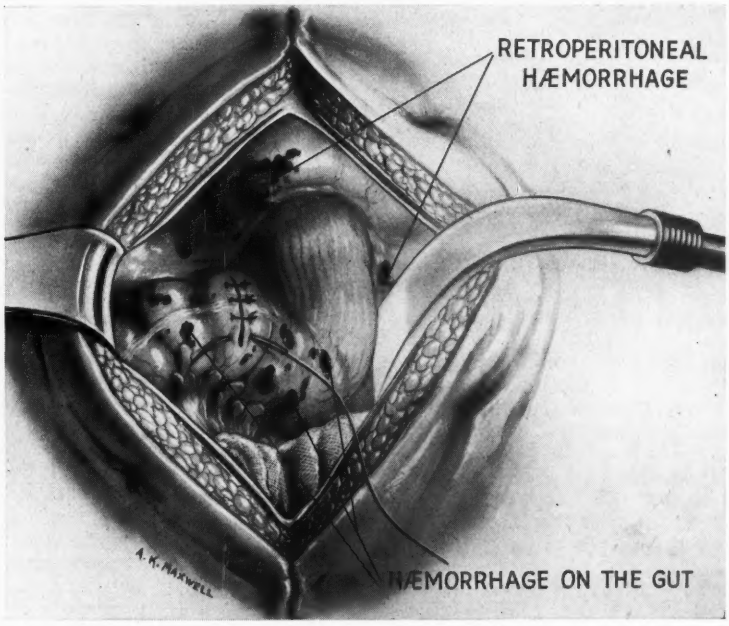


FIG. 69.—*Case* 14. A small perforation in the sigmoid colon. Numerous subserous and retroperitoneal hæmorrhages.

drink which he vomited. He was admitted to hospital eight hours after the injury. On examination he was found to be somewhat shocked, with a rapid pulse and a rigid tender abdomen. Anti-shock measures improved his condition somewhat, but it was obvious that he had an intra-abdominal lesion. Laparotomy was performed twelve hours after the injury under gas and oxygen anæsthesia. A small tear perforation was found in the sigmoid colon and numerous subserous and retroperitoneal hæmorrhages were seen (*Fig.* 69). The perforation was closed with a layer of interrupted sutures and an omental flap was sewn over the suture line. The abdomen was closed without drainage; a transfusion of 750 c.c. of blood was given during the operation. The patient made a rapid and uneventful recovery and was discharged from hospital twenty-one days after his operation.

Case 15.—A stoker, aged 32, was blown into the sea when his ship hit a mine; while supporting himself on a raft an under-water explosion occurred which caused him some abdominal pain and pain in his testicles. He was rescued in under half an hour and reached hospital about nine hours after the incident.

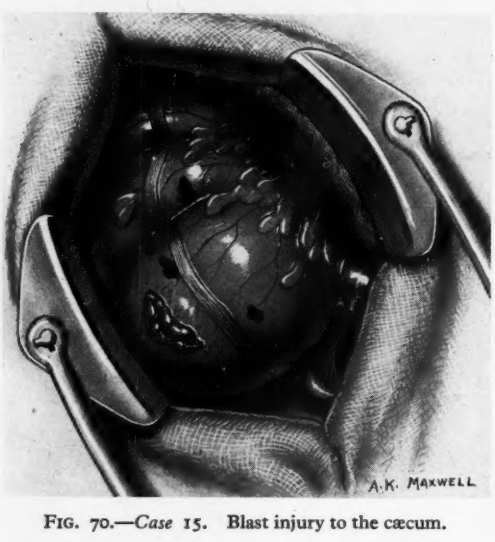


FIG. 70.—*Case* 15. Blast injury to the cæcum.

He was shocked and complained of abdominal pain, but the abdomen was not rigid or tender and he had not vomited. He continued to improve for the first ten hours in hospital and slept most of the time. However, he started to vomit at two-hourly intervals and complained of increasing abdominal pain. His abdomen was now distended and very tender in the right iliac fossa. His general condition was good, pulse 102, temperature 99·8°, respiration 20. Twenty-six hours after the injury laparotomy was performed through a right paramedian incision. Subserous and retroperitoneal hæmorrhages were seen and a perforation of the cæcum exposed (*Fig.* 70). The perforation was closed with a layer of interrupted sutures and a flap of omentum stitched over this area. The abdomen was closed without drainage. Recovery was uneventful, the patient passing some tarry stools for the first week, but after this period the motions were normal. Radiography of the chest revealed evidence of blast lung, but the clinical signs were negative.

Case 16.—A sailor, aged 21, a shipmate of *Case* 15, was similarly affected, but complained of abdominal pain and vomiting immediately after the under-water explosion occurred. When rescued, he was obviously ill and was given ⅓ gr. morphine. When admitted to hospital he was still very shocked and did not respond to the usual anti-shock treatment, in spite of the fact that this included a transfusion of 800 c.c. of blood. The abdomen was tender all over and very rigid and he was expectorating blood-stained sputum. The clinical picture was one of a ruptured viscus and twenty hours after the injury laparotomy was performed under pentothal anæsthesia. On opening the abdomen, gas, blood, and intestinal contents escaped. Multiple perforations were found in the ileum and cæcum, six in all, and very extensive and massive retroperitoneal hæmorrhages were seen. The perforations were closed with interrupted sutures, a drainage tube was inserted down to the pelvis and the abdomen closed in layers. The patient died six hours later. No post-mortem examination was performed.

Case 17.—A sailor, aged 33, a shipmate of *Cases* 15 and 16, was rescued, having undergone similar experience to those two cases. On admission to hospital he was very shocked and complained of abdominal pain. Examination revealed some abdominal distension, tenderness, and rigidity. Blood transfusion (750 c.c.) was given with some benefit, but the patient began to vomit and the clinical picture was that of a ruptured viscus. Eighteen hours after the injury the abdomen was opened and a large tear was discovered in the transverse colon; the tear passed down into the transverse mesocolon. There were numerous subserous and retroperitoneal hæmorrhages scattered about all over the abdomen. The perforation was closed with interrupted sutures and these sutures reinforced with a large omental graft. The abdomen was closed without drainage. A second blood transfusion was given following the operation, but the patient gradually sank and died twelve hours after the operation. Autopsy revealed peritonitis and very large retroperitoneal hæmorrhages, as much as half a pint of blood being found in front of the right kidney. There were no other abdominal injuries, but the lungs showed well-marked hilar hæmorrhages.

Case 18.—A fireman, aged 28, was swimming towards a raft after his ship had been sunk by enemy action when an under-water explosion occurred about two hundred yards away. He felt an acute pain in his belly and promptly vomited; he also experienced pain in both his testicles and noticed that he had lost the use of his legs. His lifebelt kept him afloat but he felt very ill and wished to die. He noticed that he could move his legs just before he was rescued, which was about half an hour after the explosion. He arrived in hospital twenty hours after his injury in a very shocked state. He was vomiting and had a very anxious expression. He was given a blood transfusion of 800 c.c. and appeared somewhat better. His abdomen was distended, rigid, and tender, and remained so for six hours, when it was decided to perform a laparotomy. Gas and oxygen anæsthesia was administered and the abdomen opened through a paramedian incision. Definite peritonitis was present and several perforations, four in all, were seen in the last loops of the ileum. There were massive retroperitoneal hæmorrhages and multiple subserous ones. The perforations were repaired with purse-string sutures and the abdomen closed, a drainage tube being inserted down to the pelvis. The patient died seven hours later. No post-mortem examination was made.

Case 19.—A sailor, aged 42, was rescued from the sea after his ship had been sunk by enemy action. While in the water, he and some of his shipmates were dive-bombed by an enemy aircraft and one bomb exploded beneath the surface about a hundred and fifty yards away from him. He felt acute abdominal pain and was nauseated for some time. He also had pain in both testicles and his legs appeared to be paralysed and he could not move them. He was rescued about an hour after the bombing, and in the interval he found that he could move his legs again. He was admitted to hospital twenty-four hours later in a very shocked condition. Temperature 101°, pulse 120, and respirations 24. His systolic blood-pressure was 90. Every attempt was made to treat the shock and 1000 c.c. of blood were given intravenously. The abdomen was distended, tender, and rigid, and the patient was constantly trying to vomit. His condition improved somewhat after the transfusion, but the abdominal condition remained the same and it was evident that an abdominal lesion was present.

Thirty hours after the injury the abdomen was opened under intravenous anæsthesia which was given through the blood transfusion tube. On opening the abdomen, several perforations were found in the ileum and cæcum. There were massive retroperitoneal hæmorrhages and scattered subserous hæmorrhages throughout the small and large intestine. The perforations were closed with interrupted sutures and dusted with sulphanilamide powder. There was definite peritonitis present and large flakes of adherent lymph were seen on the loops of the terminal ileum. A drainage tube was placed in the pelvis and the abdomen closed. A second transfusion was given, but the patient died seven hours after the completion of the operation. No post-mortem examination was obtained.

Case 20.—A sailor, aged 23, was rescued from the sea two hours after his ship was sunk. As the ship disappeared under the water a large under-water explosion occurred which was thought to be due to the bursting of one of the boilers. He was about one hundred and fifty yards away at the time and felt a sharp stabbing pain in his abdomen and felt sick. He was able to continue swimming and eventually reached a raft and was dragged on to it by some of his pals. He was admitted to hospital ten hours after the incident. On examination, his condition was found to be good, no signs of shock were present, but he had some abdominal tenderness in the right iliac fossa and some rigidity. After four hours in hospital the abdominal rigidity and tenderness increased and the patient vomited. Laparotomy was performed under gas and oxygen anæsthesia and a tear perforation of the cæcum was discovered (*Fig.* 71). There were some retroperitoneal and subserous hæmorrhages. The perforation was closed with interrupted sutures, and the omentum was then sewn over these. The abdomen was closed without drainage. The patient made an uninterrupted recovery.

Summary.—In these 20 cases which were submitted to operation there were 10 deaths, i.e., a mortality of 50 per cent. The commonest lesions were retroperitoneal and subserous hæmorrhages, which occurred in all cases. Perforations of the cæcum were present in 9 cases and in the ileum in 7 cases, while multiple perforations were present in 4 cases. Late perforations occurred in 2 cases, the cause being probably

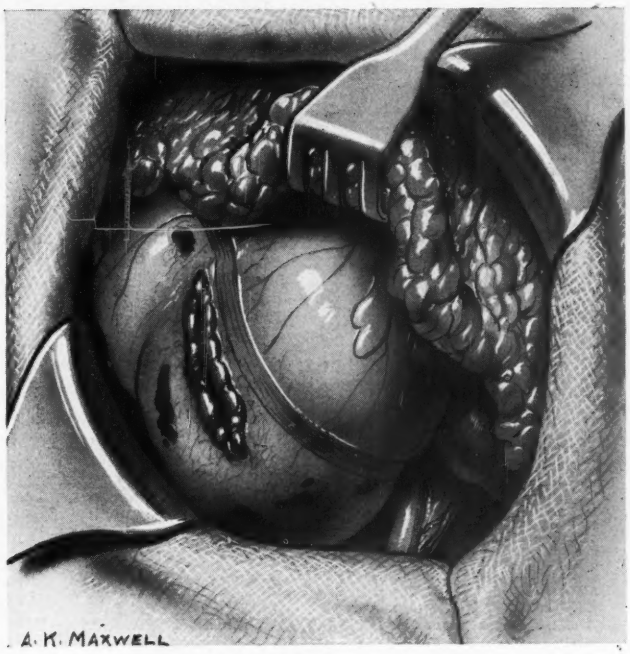


FIG. 71.—*Case* 20. Blast injury to the cæcum.

hæmorrhages initiated by the primary injury. These local hæmorrhages in the wall of the gut gradually became infected and burst into the peritoneal cavity, causing the perforation. This idea is well supported by the experimental evidence which is given at the end of this paper.

The actual gut lesions varied from intramural hæmorrhages to actual laceration of the intestinal wall. The large intestine suffered more than the stomach or small bowel—14 cases out of the total of 20. The reason for this is twofold: first, the effects of blast are always more severe on air-filled cavities; and secondly, the large intestine is not so muscular as the stomach or small bowel.

A LATE SURVEY OF 80 CASES INJURED BY IMMERSION BLAST WHICH RECOVERED WITHOUT OPERATION

These 80 cases consisted of naval ratings, merchant seamen, civilians, and others who received abdominal lesions from under-water explosions. The commonest symptom was abdominal pain, which persisted for from three days after the injury to three months in some cases. Melæna was present in 82 per cent of these cases and in some persisted for four months. In 20 per cent there was a history of hæmoptysis and in 14 per cent hæmatemesis was reported. There

was no history of any external injury in any of the cases.

The cases when seen in England were for the most part symptom-free, but a few complained of intermittent spasmodic abdominal pain and occasional melæna. Barium meal and enema examinations did not reveal any abnormality in the cases which were submitted to this form of investigation.

Out of 32 cases in which sigmoidoscopy was performed only 2 revealed any definite abnormality, and in these cases small scattered petechial hæmorrhages could be seen high up on the rectal wall and in the lower sigmoid. Examination a month later revealed normal mucous membrane.

In 4 cases the patients had suffered from immersion blast on two occasions.

From examination of available records it appears that cases which recover from the immersion blast very rarely suffer from any permanent effects. It may well be that some of these cases suffered from actual perforations which, being small, healed of their own accord, the omentum playing a protective role. In these cases adhesions will probably have formed and intestinal obstruction may be a late complication; but time alone will reveal this.

EXPERIMENTAL INVESTIGATION

The initial aim of the experimental work was to find out whether the depth of immersion of the animal played any part in determining the type and severity of lesions developing as the result of an under-water explosion.

Since intestinal damage resulted in all of the animals, special attention was directed to a study of this. Most of this section is therefore concerned with a description of the gut lesions.

The set-up of the experiment was much the same as that described in our previous paper (Cameron, Short, and Wakeley, 1942). In the present investigation, however, the animals were suspended by means of lines at a distance of 20 ft. from a 5-lb. charge of T.N.T. The pressure so generated was estimated, we were told, as reaching 1100 lb. per sq. in. for one ten-thousandth of a second.

Sixteen goats were used, 8 with their chest and abdomen immersed in the water, 8 with the abdomen alone immersed. Immediately after the explosion 4 goats were found to be moribund, 1 was described as "shocked", 1 goat had been drowned, 1 was dead as the result of the explosion. The drowned goat proved to have suffered from the effects of the depth charge prior to drowning. Four monkeys were also included for other purposes; no reference is made in this paper to them.

Surviving animals were killed at once and autopsy carried out one to two hours later.

Much material was fixed in 10 per cent formol saline and formol alcohol for histological investigation after paraffin embedding. Sections were stained with Ehrlich's acid hæmatoxylin and eosin, Weigert's iron hæmatoxylin and van Gieson, Weigert's elastic stain, Mallory's aniline blue orange-G stain. Serial sections of representative hæmorrhages in the intestine were also cut.

The alimentary canal of 10 goats from the commencement of the duodenum to the anus was preserved in 10 per cent formol saline, carefully opened and cleaned out, and the distribution of the lesions was plotted on a scale map. Our statements concerning such points may be regarded, therefore, as reasonably accurate.

Macroscopical Examination.—The main findings are set out in *Table I*, from which it is seen that the lungs and intestines were chiefly affected, both in animals with chest and abdomen immersed and with abdomen alone immersed. The pulmonary lesions were similar to those described in our former paper. They were

Table I.—INCIDENCE OF LESIONS IN 16 GOATS EXPOSED TO UNDER-WATER EXPLOSION WITH (*a*) CHEST AND ABDOMEN IMMERSED, (*b*) ABDOMEN IMMERSED

GOAT	HEART	LUNGS	INTESTINES	LIVER AND GALL-BLADDER	PANCREAS	SPLEEN	KIDNEYS	BLADDER	THYMUS	ADRENALS	SOFT STRUCTURES
I. Chest and Abdomen Immersed.											
449	−	+	+++	−	−	−	−	−	−	−	−
677	−	++	+++	−	−	−	−	−	−	−	−
687	−	+++	++	±	−	−	±	−	−	−	−
689	−	+++	+++	−	−	−	±	−	−	−	−
695	−	+++	+++	−	−	−	−	−	−	−	−
708	−	++	++	−	−	−	−	−	−	−	−
713	−	++	++	−	−	−	−	−	−	−	−
716	−	±	+++	−	−	−	−	−	−	−	−
II. Abdomen Immersed.											
444	−	++	++	±	−	−	−	−	−	−	−
455	−	+	+	−	−	−	−	−	−	−	−
686	−	+	++	−	−	−	−	−	+	+	−
691	−	++	+++	−	−	−	−	−	−	−	−
703	±	±	+++	−	−	−	−	−	−	−	−
706	−	±	+++	−	−	−	−	−	−	−	−
707	±	++	+++	−	−	−	−	−	−	−	−
712	−	++	+++	−	−	−	−	−	−	−	−

±, ±, +, ++, and +++ indicate increasing order of severity of lesions.

somewhat more severe in animals with chest and abdomen immersed than in those with abdomen alone immersed. Thus if numerical estimates are made by giving arbitrary values to the lung lesions (for example ± = 1, + = 2, ++ = 3, +++ = 4), the former group is about 40 per cent more severe than the latter.

Slight hæmorrhage was also noted occasionally in the heart, liver, kidneys, thymus, and adrenals. The soft tissues of the body wall escaped, and no lesions were found in the gall-bladder, urinary bladder, spleen, or bones. The testes were the site of hæmorrhage in a few animals (*Fig.* 72), monkeys being more often affected than goats.

Table II.—Incidence of Intestinal Lesions

	Small Intestine		Large Intestine	
	Present	Absent	Present	Absent
Chest and abdomen immersed	7	1	8	0
Abdomen immersed	8	0	8	0

Since the main object of this paper is to discuss the intestinal lesions resulting from under-water explosions, we shall describe these in some detail. In this particular experiment, such lesions were constant, occurring in each of the 16 goats. *Tables II* and *III* summarize the distribution of the changes in the gut. It appears that the incidence was middle and lower thirds of the large intestine, upper third of large intestine, upper third of small intestine, middle third of small intestine, and lower third of small intestine in that order (*Table III*). Large-bowel lesions were very much more striking than those in the small intestine (*Table IV* and *Fig.* 73). There was, however, a close similarity in the nature of the lesions whether occurring in the large or small intestine. These included: (1) hæmorrhage in the gut wall; (2) perforation of the gut with prolapse of mucous membrane; (3) effusion of blood into the gut lumen, with bleeding per rectum; (4) mesenteric hæmorrhage.

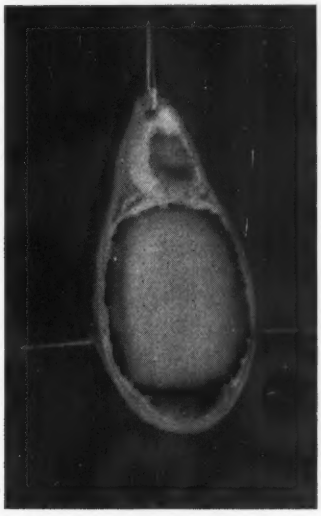


Fig. 72.—Testis of monkey, showing capsular and sub-capsular hæmorrhage.

Table III.—Distribution of Intestinal Hæmorrhage in 10 Goats Exposed to Under-water Explosion

Goat	443	444	449	454	695	691	703	707	712	716
Small Intestine:										
Upper third	±	++	+	+	+	±	±	+	+	±
Middle third	0	+	+	±	±	±	0	0	±	±
Lower third	0	±	±	±	±	±	±	0	0	0
Large Intestine:										
Upper third	++	±	++	+	+	++	±	+	+	±
Middle third	+++	++	+++	++	+	++	+	++	++	+
Lower third	++	++	++	+++	++	++	++	++	+++	++

Table IV.—Severity of Intestinal Lesions

	Small Intestine			Large Intestine		
	Severe	Moderate	Slight	Severe	Moderate	Slight
Chest and abdomen immersed	2	2	3	8	0	0
Abdomen immersed	3	0	5	8	0	0

Hæmorrhage into the gut wall took the form of:—

1. Isolated pin-point hæmorrhages, single or in small groups.

2. Fine linear groups of discrete or fused petechiæ sometimes extending in annular fashion around the lumen.

3. Well-defined narrow annular bands of hæmorrhage, usually associated with a small amount of effused blood in the gut lumen (*Fig.* 74). Such ' whipcord ' lines were often regularly spaced through several coils of intestine.

4. Broad bands, produced by fusion of annular lines, with large masses of blood-clot inside the lumen, attached to the mucosa of the bands

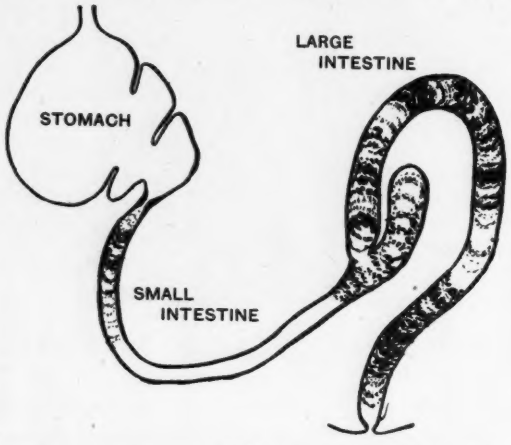


FIG. 73.—Diagram showing distribution of lesions in alimentary canal of goats. The small intestine has been considerably reduced in length.

(*Fig.* 75). Such clots were sometimes large enough to obstruct completely the lumen (*Fig.* 76). Occasionally polyp-like masses of clot projected into the lumen, resembling at first sight the characteristic papillomata found in this region. Perforation of the gut was common with this type (*Fig.* 77).

5. Retiform markings occasionally. These were small and imperfectly formed, resembling " question marks " ; or complete, as rings or extensive networks. They followed the anatomical course of the large vessels in the intestinal wall.

In general, hæmorrhage was more severe along the antimesenteric region, but it was primarily and essentially mucosal, involving the submucosa and outer coats only in the more severe cases, especially when there was perforation of the gut.

Perforation of the gut occurred in 9 of the 16 goats, being slightly more frequent in the large intestine than in the small (*Table V*). Three perforations were found in one animal, 4 in another ; in the remaining 7 animals, perforation was single. When multiple, perforations were found in both small and large intestine. The lower third of the ileum, the cæcum, ascending colon, and rectum were the usual sites involved. Very little hæmorrhage had occurred into the peritoneal cavity, the gap in the gut wall being closed by a small clot and prolapsed mucous membrane. Considerable bleeding into the lumen was constant. The perforation was oval shaped or irregular, seldom wider than a few millimetres in both main axes and closely resembled that produced by a small bullet. No fæcal pellets were found free in the peritoneal cavity, so that perforation could not be attributed to the forcing of such a pellet through the gut wall.

Effusion of blood into the lumen was constant, free blood being found on the injured mucosa, sometimes mixed intimately with fluid gut contents in the small intestine, or when massive occurring as large clots partly or completely filling the gut lumen. Bleeding from the anus was very common (10 out of 16 animals—*Table VI*), and was now and then associated with petechiæ around the anal margin. In these cases injury of the rectum was severe.

Mesenteric hæmorrhage was found in loops of the ileum of 3 animals (*Table VII*). In one

Table V.—PERFORATION OF INTESTINE

	SMALL INTESTINE			LARGE INTESTINE		
	Present	Absent	Percentage showing Perforation	Present	Absent	Percentage showing Perforation
Chest and abdomen immersed	1	7	12·5	3	5	37·5
Abdomen immersed	4	4	50	3	5	37·5

Table VI.—BLEEDING FROM RECTUM

	PRESENT	ABSENT	PERCENTAGE SHOWING RECTAL BLEEDING
Chest and abdomen immersed	3	5	37·5
Abdomen immersed	7	1	87·5

Table VII.—MESENTERIC HÆMORRHAGE

	PRESENT	ABSENT	PERCENTAGE SHOWING MESENTERIC BLEEDING
Chest and abdomen immersed	1	7	12·5
Abdomen immersed	2	6	25

instance it was fairly severe, forming a hæmatoma several centimetres in width, tracking towards the root of the mesentery from the mesenteric border of the intestine.

With severe hæmorrhage, stripping of the mucous membrane could be made out, and pieces of the mucosa could be picked from the blood in the gut cavity. With the smaller hæmorrhages, break in continuity of the mucous membrane was likewise obvious. On the other hand, spread of blood into the outer coats was uncommon and even with perforation was restricted in extent.

Unaffected gut showed no abnormality in its blood distribution nor was it displaced from its usual position. The omentum was not associated with the perforation.

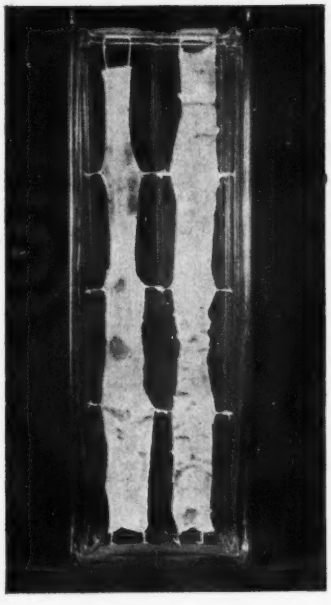


FIG. 74.—Colon of goat, showing fine linear groups of discrete and fused petechiæ and broader bands in process of formation.

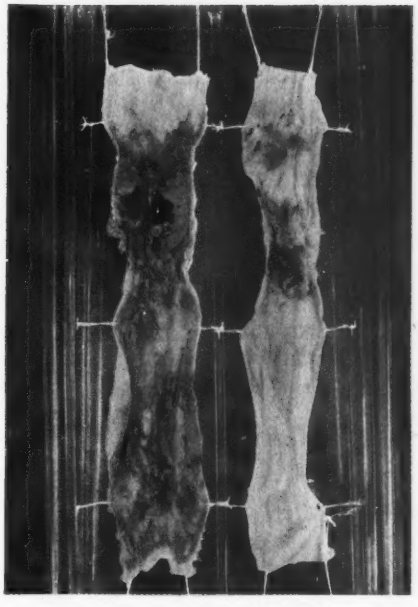


FIG. 76.—Ileum and colon of goat. Massive hæmorrhage in wall and lumen of ileum, obstructing the pathway. Polypoid clot in colon, partly obstructing the lumen.

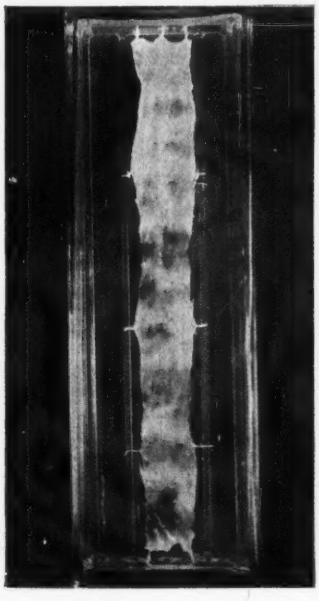


FIG. 75.—Colon of goat, showing broad annular bands of hæmorrhage.

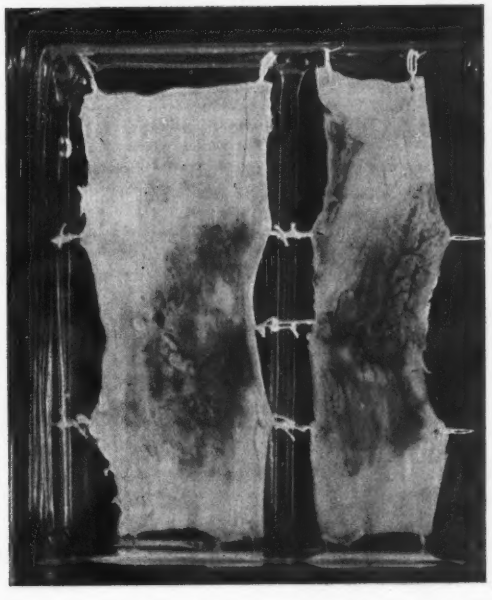


FIG. 77.—Colon of goat, showing two perforations surrounded by extensive hæmorrhage in wall and lumen.

The following gives a comparison between lesions resulting from complete and partial submersion of animals :—

Chest and Abdomen Immersed

1. Lung lesions somewhat more severe (40 per cent more severe as a rough estimate).
2. Rib markings in 75 per cent cases.
3. Large bronchial and tracheal clots in 50 per cent cases.
4. Hæmorrhages in lungs mostly basal and marginal.
5. Intestinal hæmorrhage in all.
6. Severity of intestinal lesions greater in large intestine.
7. Perforation more frequent in large gut than in small gut.
8. Mesenteric hæmorrhages slightly more frequent in abdomen immersed cases.
9. Bleeding per rectum in 37·5 per cent cases.

Abdomen Immersed

1. Lung lesions less severe.
2. Rib markings in 12·5 per cent.
3. Large bronchial and tracheal clots in 12·5 per cent cases.
4. Hæmorrhages in lungs mostly basal, medial and marginal.
5. Intestinal hæmorrhage in all.
6. Severity of intestinal lesions greater in large intestine.
7. Perforation slightly less frequent in large gut.
9. Bleeding per rectum in 87·5 per cent cases.

It thus appears that lung lesions are somewhat more severe, rib markings much more frequent, bronchial and tracheal clots more common in animals whose chest and abdomen were immersed during the under-water explosion. Bleeding per rectum and, perhaps, incidence of mesenteric hæmorrhage were greater when the abdomen alone was immersed. The incidence and severity of gut lesions was about the same in both types of experiment.

Microscopical Examination.—There is a striking similarity in intestinal lesions of all the experimental animals.

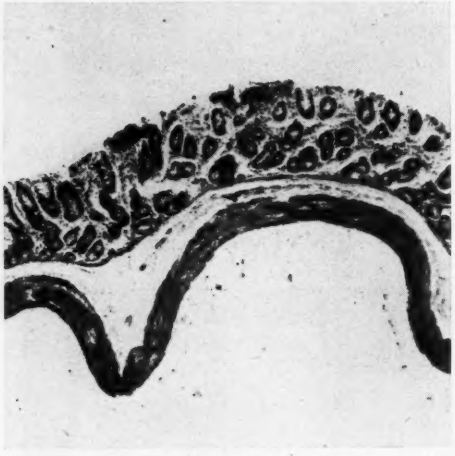


FIG. 78.—Small hæmorrhages at surface of gut mucosa, one involving outlet of a gland.

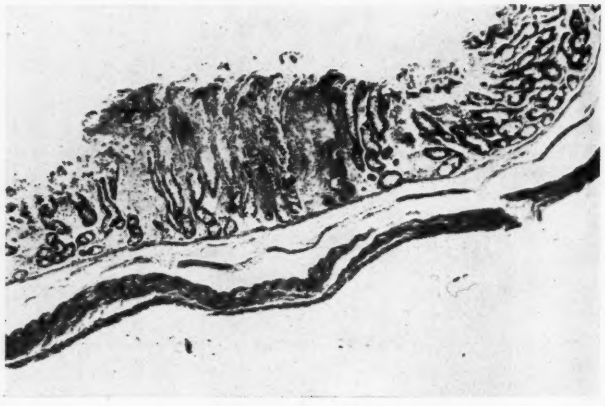


FIG. 79.—Mucosal hæmorrhage extending to muscularis mucosæ, with destruction of glands.

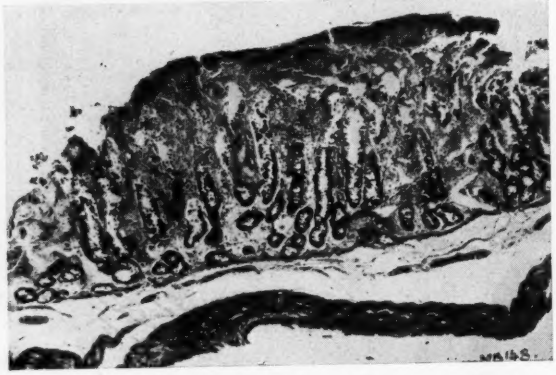


FIG. 80.—Mucosal hæmorrhage, showing scattering of glandular epithelium, the deeper cells persisting. Blood-clot extends into the lumen.

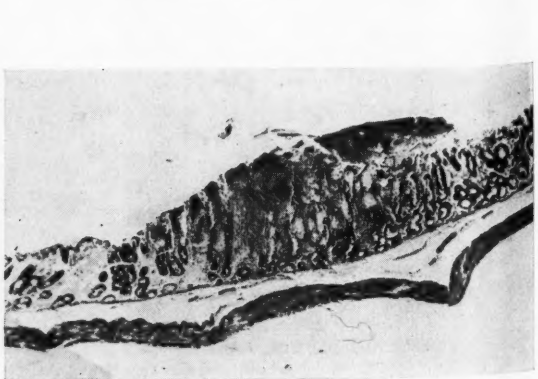


FIG. 81.—Mucosal hæmorrhage, with tracking of blood along surface of gut in the direction of peristalsis.

Lesions are essentially mucosal in position, the other layers of the large and small intestine being rarely affected, except where perforation occurs.

In the smallest lesions, the surface of the mucosa shows groups of effused red blood-corpuscles between the gland outlets, the lining epithelium having completely disappeared, or showing partial detachment (*Fig.* 78). Larger hæmorrhages extend down to the muscularis mucosæ where they usually stop quite abruptly (*Fig.* 79). There is 'scattering' of epithelial cells (*Fig.* 80), especially of the glandular cells, and large superficial flakes of these may be discerned in the blood oozing from the surface layers (*Fig.* 81). Many of the glands look as if they had been forcibly elongated and broken.

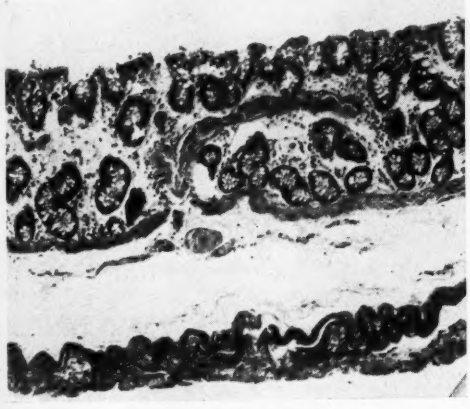


FIG. 82.—Normal colon, showing large vein extending through mucosa.

The more superficial half of the glands is destroyed, the deeper portion appears normal. There can be no question of confusion with post-mortem changes since our material was often enough fixed within an hour and a half of death and great care in handling the material was insisted upon. The smallest lesions thus resemble small 'ulcers' in the surface layers of the mucous membrane, as if tiny pieces of epithelium and the tops of capillary loops had been forcibly scooped out. Apparently groups of mucosal capillaries had simultaneously been injured and burst, liberating blood which escaped around the vessels into the supporting mucosal tissue or directly into the gut lumen. It may be pointed out that the so-called capillaries of the small and large intestinal mucosa are very wide when distended with blood, resembling sinuses in their structure. We have injected a number of areas of gut in normal goats with carmine gelatin under physiological conditions, and have been impressed by the capacity of the smallest vessels which reach the surface of the intestines. *Fig.* 82 is a microphotograph of a large mucosal vessel. It is not surprising, therefore, that when these vessels are ruptured bleeding may occur quickly and sometimes on a large scale. It is rare for the larger veins and arteries in the submucosa and outer coats to be affected, but every now and then we have come across damage of one of these; *Fig.* 83 shows a rupture of an arteriole.

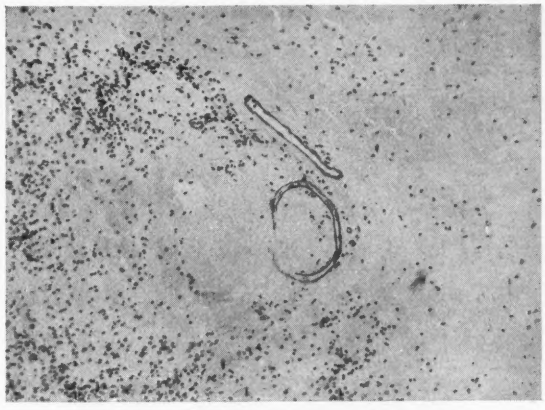


FIG. 83,.—Rupture of arteriole in submucous coat, with hæmorrhage. Stained by Weigert's elastica method.

Occasionally, the hæmorrhages in the mucosa develop some little distance from the surface, about the middle of the layer, and sometimes they are seen close to the muscularis mucosæ spreading longitudinally along the wall (*Fig.* 84). Eventually these track towards the surface.

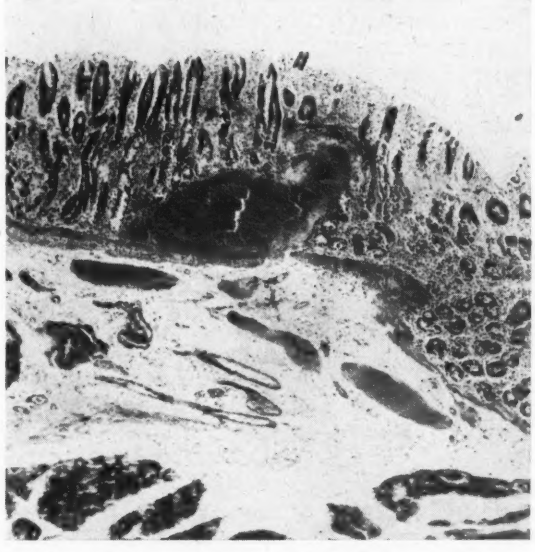
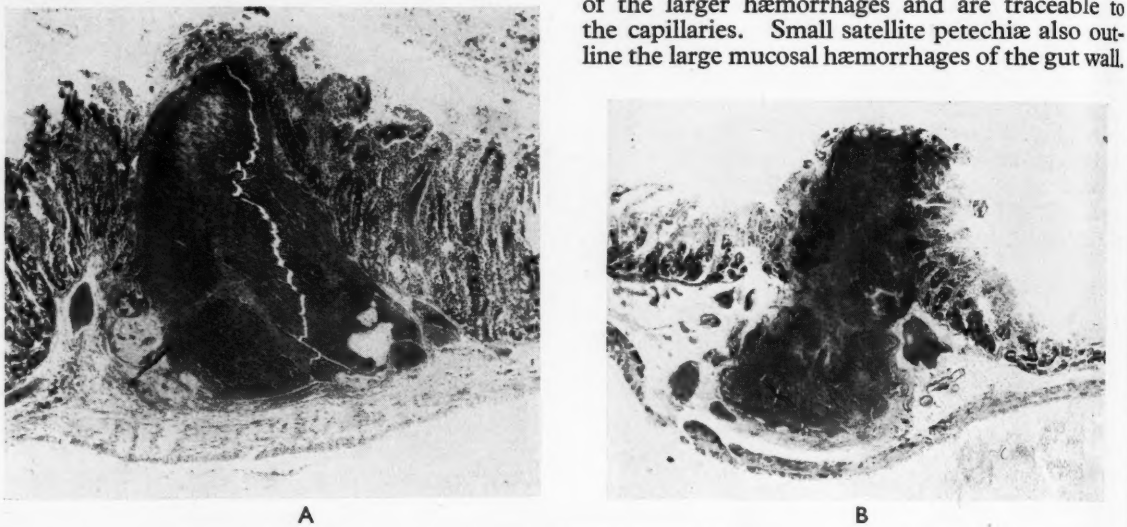


FIG. 84.—Hæmorrhage commencing near muscularis mucosæ and extending towards surface of mucosa.

It is rare for the muscularis mucosæ itself to show red-cell effusion or tearing; very occasionally, hæmorrhage extends through it to the submucosa and muscular coat (*Fig.* 85, A, B), and may lead to perforation.

Examination of several hundreds of serial sections has failed to convince us of any regular association between anatomical arrangement in the gut wall and localization of hæmorrhage.

There is no relation to lymphoid follicles in the wall nor to sites of penetration of the deep muscle by the larger vessels from the mesentery. The retiform markings appear to be hæmorrhages outlining the medium-sized vessels anastomosing in the submucosa or serosa, but these are infrequent.



A B

FIG. 85.—A, B, Large hæmorrhage extending through mucous and submucous coats to muscle.

We have emphasized the annular distribution of hæmorrhage as a constant finding. Since there is no anatomical explanation of the nature of this type of hæmorrhage, we are forced to conclude that it is associated with the explosion wave either acting directly on the structures in the gut wall or through the mediation of intestinal contents, perhaps gas. It is certainly striking how often air-containing or gas-containing organs are severely damaged by under-water explosions. On the other hand, the small intestine has not uncommonly shown similar lesions to those in the large intestine, yet, so far as we know, it contains little gas in the goat. Moreover, the huge stomach often enough is air- or gas-containing, yet it is rare to find lesions in its wall. The possibility of an association with the hard fæces in the large intestine has been considered. We carefully examined the large gut *in situ*, disturbing it as little as possible, but could make out no definite relation between the annular bands and the position of scybalæ. Moreover, bands of hæmorrhage are found often enough in the small intestine where the gut contents are fluid so that obviously hardness of fæces cannot play the determining part in production of annular hæmorrhage. All of the factors concerned in localization of the damage have not been discovered.

Perforations show a tear through all layers of the gut wall. Ragged torn ends of the mucous membrane prolapse through the gap, and bleeding, usually on a small scale, leads to the formation of a small clot in the gap, partly closing it. Sometimes the clot appears moulded to the perforation and may even project outwards from the serous coat. We have not found any localizing factor for the perforations.

With mesenteric hæmorrhage, there is damage of large vessels (chiefly veins) as well as capillaries. Petechiæ are common around the margins of the larger hæmorrhages and are traceable to the capillaries. Small satellite petechiæ also outline the large mucosal hæmorrhages of the gut wall.

Summary.—

1. Lung lesions were somewhat more severe, and bronchial and tracheal clots more common, in goats whose chest and abdomen were immersed during under-water explosions than when the abdomen alone was immersed.

2. Bleeding per rectum and mesenteric hæmorrhage were more marked when the abdomen alone was immersed.

3. Intestinal lesions were common in both types of experiment and included small and large hæmorrhages in the mucosa, perforations, bleeding into the lumen, mesenteric hæmorrhage.

4. The histology of these lesions is described and their nature briefly discussed.

Our thanks are due to Surgeon Vice-Admiral Sir Sheldon Dudley, F.R.S., Medical Director-General of the Navy, for his kindly interest and help in this investigation; also to Surgeon Captain A. Fairley, R.N., Surgeon Commanders E. R. P. Williams, R.N., and G. P. McCullagh, R.N.V.R., Captain W. P. Blount, R.A.V.C., and Mr. R. McV. Weston, for valuable assistance in this investigation. Messrs. F. Burgess and J. M. Allen were especially helpful at the post-mortem examinations.

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A CLINICAL STUDY OF INJURIES OF THE ABDOMEN DUE TO UNDER-WATER EXPLOSION

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and Surgeon Lieut.-Commander C. P. HAY, R.N.V.R.

On April 9, 1942, the Hospital Ship *Vita* was fifteen miles off and travelling in the opposite direction to H.M. Ships *Hermes* and *Vampire* when they were sunk by enemy dive-bombers. Two hours later Vita's boats were in the water picking up survivors and casualties. The operation was completed about five hours after the action began. Out of a total of 595 survivors there were about 140 badly wounded, of whom 20 died within twelve hours. The wounds were of all types, including burns, but among them were a number of patients complaining of abdominal pain of varying severity, following injury to the abdomen by under-water explosion. These men had been in the vicinity of exploding depth-charges, and three were involved by the explosion of the destroyer's magazine. Some of these men gave a graphic description of how the explosion blew them right out of the water. There were no direct gunshot wounds of the abdomen in these patients, and it is the purpose of this paper to try to record the impressions gained at the bedside, at operation, and at post-mortem. Particularly is it intended to record the management of these patients, for they present many interesting clinical problems. Unfortunately, detailed notes on the clinical findings and progress were frankly impossible. The majority were landed 48 hours later, and during that time the entire medical and sick-berth staff were actively engaged in feeding, nursing, and life-saving measures, so that there was little time for detailed note-taking. Operative findings were recorded. In the rush and scurry associated with the unexpected influx of patients of this type, medical officers are so actively employed in sorting out patients for transfusion, for operation, etc., that notes are inevitably scanty.

This paper, then, is in the nature of a clinical study, and the literature has not been referred to, for although we are familiar with articles on the effects of under-water explosion, this was our first personal experience of this type of injury, and it is felt that independent observations may be of some value. Therefore, it is proposed merely to describe the patients, 16 in number, all of whom were admitted within a relatively short time of their injury, the management of them, the results obtained, and the personal conclusions reached.

CLINICAL AND PATHOLOGICAL FINDINGS

The clinical picture varied very considerably, from those who climbed aboard unassisted and complained only of abdominal pain, associated with tenderness and rigidity of the abdominal wall, to those who were profoundly shocked when first seen and obviously suffering from a severe intra-abdominal catastrophe. This latter group resembled in many respects the patients seen in civil practice with severe abdominal injuries due to direct violence. But, apart from them, the outstanding impression gained of the group as a whole was the apparent fitness of the men, and the absence of more than a moderate degree of shock, even in those who later proved to have gross intra-abdominal lesions, and this in spite of two or three hours' immersion in the sea.

The presenting symptom in every patient was abdominal pain, varying from a dull ache to a pain of agonizing character, and this was associated with a corresponding variation in the physical signs.

From the outset it was realized that the problem would be to decide which patients demanded immediate laparotomy, which should be left alone and kept under careful observation, and which were going to die no matter what was done.

Of the 16 patients under consideration, one died within a short time of admission. Another died six days later as a result of severe lung injury sustained at the same time as his abdominal lesions, and due to the same cause; this latter was the only one subjected to post-mortem examination. Owing to pressure of work and tropical conditions the earlier patients who died were buried at sea almost immediately.

Six patients were operated on. Of these, two recovered, one having had two ileal perforations sutured, and the other a diffuse peritonitis without discernible perforation, and a post-operative pelvic abscess which developed later. Four died, three having sustained perforations of one or more hollow viscera, and one with subserous ecchymoses of the mesentery and small intestine, and, in addition, a severe lung injury. This last was latent at the time, but became manifest later.

The remaining eight patients recovered without operation, and did not develop any unpleasant sequelæ.

Thus, of the 16 patients arriving on board alive, 6 died.

Many men having suffered similar injury must have died in the water.

DESCRIPTION OF THE PATIENTS

When a preliminary survey of the 16 patients was made, two were considered to be suffering from such a degree of shock, associated with

severe abdominal and chest injuries, that operative interference was impossible and conservative measures were adopted. Both died, one, *Case* 1, within a few hours of admission; he was buried without post-mortem. The other, *Case* 2, was too ill to land with the majority of the patients and he was retained on board, where he died six days later. On admission he was desperately ill. He had vomited blood and had a brisk rectal hæmorrhage. His abdomen was tender and resistant to palpation. At the same time he complained of severe backache and difficulty in micturition. Not only had he these abdominal symptoms, but his condition was complicated by the fact that he had obvious pulmonary damage in addition to the inhalation of oil fuel. He was spitting up blood, and at first a copious quantity of oil fuel. It was thought that he had little chance of survival, and only conservative treatment and general nursing measures were adopted. He had one more rectal hæmorrhage, and his abdomen slowly became tumid. There was never, however, any clear indication for laparotomy, and anyhow the gravity of his general condition made this impossible. He died of respiratory failure six days after his injury. At post-mortem his lungs showed the typical effects of explosion injury. They were quite solid with blood and resembled a pneumonia at the stage of red hepatization. The abdomen showed a diffuse plastic peritonitis, but no evidence of perforation. There were about two pints of purulent non-smelling fluid in the pelvis, but no localized abscess formation. A large submucous hæmatoma of the hepatic flexure was present, and in association with this there was a mucous rupture, the cause of his melæna. There were similar areas in the small intestine where the mucous membrane had ruptured, and, in addition, multiple subserous ecchymoses of the ileum and its mesentery. No bruising of the gastric mucosa was found, and there was no evidence of bruising of the abdominal wall or parietal peritoneum. The right kidney had a few petechiæ of the pelvic mucosa.

The next three patients appeared to demand early laparotomy. The first, *Case* 3, presented little difficulty in diagnosis. On admission he was shocked, with a pulse-rate of 120 per minute. He complained of severe generalized abdominal pain, worst low down, and on examination he presented a rigid, slightly distended, abdomen, with the maximum tenderness in the left iliac fossa. The pain had been quite unrelieved by morphia. There was no evidence of free fluid or gas in the abdomen and there were no abnormal physical signs in the chest. He was thought to have a rupture of one or more hollow viscera and was operated on accordingly six hours after his injury. The abdomen was opened under general anæsthesia. As in all patients of this series, the abdomen was opened by a mid-line incision starting above the umbilicus and ending suprapubically. The pelvic cavity of the abdomen contained about a pint of blood, mixed with fæcal matter. The serous coat of the ileum showed bruising in parts as did that of the cæcum and sigmoid colon. There were many ecchymoses in these areas and small hæmatomata of the mesentery, particularly of the terminal ileum. Two circular perforations were present on the antimesenteric border of the terminal ileum, both being about $\frac{1}{4}$ in. in diameter. In addition there was a laceration in the antimesenteric border of the sigmoid colon at its most mobile and dependent part, and through all these openings fæcal matter was exuding into the abdominal cavity. There was no evidence of any damage to the solid viscera. The colon was closed by a clamp and exteriorized through a left grid incision, a Paul's tube being tied in. The openings in the ileum were closed by a continuous suture, the pelvis mopped, and the abdomen closed over a large pelvic drain. In spite of continuous intravenous fluid and blood transfusion he died eight hours later.

The next patient, *Case* 4, was similar clinically. There was some degree of shock present. The pulse-rate was 100, and remained in that region up to the time he was operated on eight hours after his injury. He complained of severe generalized abdominal pain, worst in the left upper quadrant, and there was also pain at the left shoulder-tip. There was generalized and marked abdominal rigidity with maximum tenderness in the left upper quadrant. The abdomen was slightly distended. There were no abnormal physical signs in the chest. Under general anæsthesia the abdomen was opened, but apart from subperitoneal ecchymoses of the small intestine and the pelvic colon, and some slightly blood-stained free fluid, no lesion was found. There was no evidence of any perforation or rupture of a solid or hollow viscus. The diaphragm was intact. The abdomen was accordingly closed. This patient died 36 hours later showing all the signs of a severe concussion of the lungs, and there is no doubt that operation accelerated his demise, although from the amount of the lung involvement, a fatal termination would appear to have been inevitable. In view of these negative findings at operation, it seemed wise that a pause should be made and decisions about other patients reconsidered. Could rupture of a hollow viscus be so nearly simulated by bruising of the abdominal contents alone? On looking over the whole series of cases in retrospect, the answer to that question would be in the affirmative, and at the time a previous decision to operate immediately on the next patient was revised.

This patient, *Case* 5, on admission, complained of agonizing abdominal pain. His bowels opened several times and he had a small hæmatemesis whilst still on a raft. He could not pass urine and later had to be catheterized. He had received morphia whilst on a raft, though this had done little to relieve his pain. There was some degree of shock present, with a pulse-rate in the

neighbourhood of 110. The abdomen was rigid, especially in its lower part, was exquisitely tender, and slightly distended. There were no signs of free fluid in the abdomen, neither were there any abnormal physical signs in the chest. There was little doubt, when first seen, that this patient had a rupture of his bowel with spreading peritonitis, but in view of *Case* 4, and especially as the pulse was falling, operation was delayed. However, about two hours after the latter decision, and about ten hours after the injury, his pulse-rate began to rise again and there was increasing pain and rigidity. The abdomen was accordingly opened by a midline incision under general anæsthesia. The ileum was found to be ruptured in two places at its lower end. One hole was about ½ in. in diameter, and the other somewhat smaller. Both were antimesenteric and circular, and both had pouting of the mucous membrane. There was a quantity of blood in the pelvis and a diffuse fæculent peritonitis, most marked in the lower abdomen. There were, in addition, many ecchymoses of varying sizes of the bowel and mesentery, and one large subserous hæmatoma at the ileocæcal junction. The perforations were closed by sutures, the pelvis cleaned, and the abdomen closed over a large pelvic drain. The ileum itself was drained through a rubber tube, tied in above the level of the lesions. In spite of continuous blood transfusion and intravenous fluids he died thirty-six hours later.

There is no doubt that this patient should have been operated on as soon as possible. The agonizing pain, the urinary difficulties, and the rigid abdomen should have been sufficient, but the experiences of *Case* 4 had influenced the decision to delay, and also it must be remembered that there were at this time under observation eleven other cases, all suffering from abdominal injury from a similar cause, and all with varying degrees of tenderness and rigidity. True, none were quite so severe as this patient, but it was considered justifiable to watch him for a short time.

The next three cases, all of which were ultimately operated upon, are of considerable interest. On admission they all complained of abdominal pain, but there were no indications for operative interference, and it was not until some time later that these appeared.

Case 6 was a man who, as he said, was literally blown out of the water by the explosion of a magazine. He had abdominal pain, but this was not severe and on admission his condition did not give rise to anxiety. Indeed, there was as much concern over his concomitant backache and inability to micturate, as over his abdomen, for while it was realized that the essential lesion was most probably an abdominal one, spinal injury had to be excluded. The abdomen was tender on examination, and there was a fair amount of resistance of the muscles, especially in the lower abdomen. With rest in bed his condition improved, his pulse remained steady, never above 100, and it was not until fourteen hours after his injury that he began to get severe abdominal pain, with rapid deterioration in his general condition, an anxious facial expression, and marked rigidity of the abdomen especially in the lower quadrants. It was then evident that some intra-abdominal catastrophe had occurred, and immediate operation was decided upon. His abdomen was opened sixteen hours after the injury, when a fæculent lower abdominal peritonitis was found. There were many plaques of lymph over the small gut, these being most marked in the region of two small perforations that were present in the terminal ileum about three feet from the ileocæcal junction. Indeed, it was only after wiping away one of these plaques of lymph that the smaller of these perforations was discovered. It was judged that the perforations had occurred at the time of injury, for there was pouting of the mucous membrane, and some free blood in the peritoneal cavity. The peritonitis was also that of some hours' standing, and it may be that a temporary closure of the perforations by natural means accounted for the comparative well-being of the patient for the first few hours. The perforations were sutured and the abdomen closed over a pelvic drain. Continuous intravenous fluids and two pints of blood were given during the next few days, and after a stormy convalescence, during which paralytic ileus and a partially burst abdominal wall were overcome, a good recovery was made, and when seen two months later the patient was well, apart from a ventral hernia, which will require repair at some future date.*

Case 7 was one of the most interesting of the series. He was admitted with the story that he had been involved in an under-water explosion. This had been followed by abdominal pain, and on admission he complained of this. There was some tenderness of the abdomen, especially low down, but his condition gave rise to no anxiety, and he was no worse than many others whom it was decided to watch. He was kept quiet, given small amounts of fluids by mouth, and a half-hourly pulse-chart instituted. His pulse never rose above 85 beats per minute, but about twenty-four hours after his injury he suddenly got very much worse, with severe lower abdominal pain. His abdomen was rigid, a little distended, his face developed an anxious expression, and there was a 'peritonitic' smell to his breath. There was little doubt that he had perforated a hollow viscus, and to all intents and purposes he resembled a patient with a straightforward duodenal perforation, except that all his signs had been stepped down. His abdomen was opened under general anæsthesia, through the usual midline incision, and there was found to be a rather foul-smelling lower abdominal peritonitis present, with a small leaking perforation

* This has since been done.

of the ileum about six feet from the ileocæcal junction. There were also many plaques of lymph and ecchymoses of the visceral peritoneum covering the bowel and its mesentery in the lower abdomen, as in *Case* 6. The perforation and abdomen were treated as in the other patients. The perforation in this case seemed to be of recent origin, for there was no pouting of the mucous membrane as in the previous cases, and the peritonitis was an early one. In addition, there was no blood in the peritoneal cavity. For these reasons it is considered that this patient had received a partial rupture of the intestine at the time of injury involving only the mucous and adjacent coats, and that actual perforation had occurred sometime later. Twenty-four hours after operation he was transferred to a shore hospital as *Vita* was urgently required elsewhere with all available beds. He appeared to be making good progress at this time and his condition was satisfactory. Six days later, however, he died of general peritonitis.

Case 8 was a boy of 19 who said he had been blown right out of the water by an explosion. On admission he complained of some abdominal pain, but settled down well and soon appeared to be out of danger. His pulse was always below 80 beats per minute, and his abdomen, which had been tender with some rigidity, improved, the rigidity disappearing altogether. About thirty-six hours after his injury, however, he complained of a return of his abdominal pain, this time much more severe in character, and his abdomen became quite scaphoid and rigid, with a slight rise of pulse to 90. It was naturally thought that this patient was similar to the previous one, *Case* 7, and he was operated on accordingly. A moderate degree of pelvic peritonitis was found with slightly blood-stained, but non-smelling, turbid fluid. There were many flakes of lymph adhering to the pelvic viscera, and there were also diffuse subserous ecchymoses. A most careful and detailed search was made of all the hollow viscera, but no sign of perforation was found. The pelvis was mopped dry and the abdomen closed without drainage. His recovery was interrupted by the development of a pelvic abscess which resolved of its own accord. Seven weeks later, when he was up and about, he had an attack of pain for which his abdomen was again opened at another hospital, and it was reported that, but for one or two adhesions, no abnormality could be found, and he has remained well since.

The remaining eight patients, *Cases* 9–16, will be considered as a group. All had suffered abdominal insult as a result of under-water explosion, all recovered without unpleasant sequelæ, and none required operation. Every one of these patients complained of persistent pain starting shortly after the injury, and showed physical signs of such injury on admission. All had some degree of resistance to palpation of the abdominal wall, and a varying amount of associated tenderness. It was noted, however, that their physical signs tended to be located more in the upper than in the lower abdomen. Some showed signs of shock, and one man had an associated lung lesion as evidenced by a slight hæmoptysis, whilst another had bruising of the abdominal wall which could be seen and felt.

On admission, *Cases* 7 and 8 were included in this group and were quite typical of it. It was only by their behaviour twenty-four and thirty-six hours respectively after admission that they differed, for in them the symptoms, although showing early improvement, later became much more severe, whilst in the remainder of the group there was a steady improvement which was maintained. It can be seen, therefore, that all these patients required careful watching, and a considerable amount of thought as to their correct management, and it should be noted that a patient must not be treated lightly even though he shows no immediate and urgent physical signs following an abdominal injury of this nature.

The physical signs in all these patients decreased steadily after admission, and the sense of well-being increased proportionately. At the end of forty-eight hours, in all but two, rigidity had entirely disappeared, although some still complained of tenderness on palpation. Subsequent follow-up has shown that none of this group required operative interference.

DISCUSSION

The main points for discussion arising out of a consideration of this series of cases are the morbid anatomy, the nature of the forces involved, and the management of the cases.

Morbid Anatomy.—From this series it is possible to classify some of the intra-abdominal lesions that will occur as a result of under-water explosion. How the damage occurs is not of importance from the point of view of pure morbid anatomy, and only the actual damage observed or deduced will be described.

The type of injury varies from a most severe and destructive form producing immediate death, to a mild one with no sequelæ other than abdominal pain and shock. That all gradations occur can be seen from the patients described in this paper. The following pathological types have therefore been separated.

Type 1.—In its most severe form the immediate shock is so gross that death follows rapidly, and such patients are rarely seen alive. This severe shock, which is in the nature of a gross splanchnic insult, is in most cases associated with rupture of viscera and with internal hæmorrhage. There may also be concomitant damage to the lungs. Occasionally such patients will be seen alive, as *Case* 1 was, but their condition is so grave that little can be done for them. The attitude adopted on this occasion was that no active treatment would be given unless there was a reasonable response to the exhibition of morphia, rest, and warmth; there were too many other patients requiring urgent attention.

Type 2.—This might be termed the classical type, and the factor determining the inclusion of a patient in this group is the perforation of a hollow viscus, the perforation having occurred at the time of injury. The amount of concomitant visceral damage varies from patient to patient, but in all cases where the force has been powerful enough to produce rupture of the intestine, there must at the same time be damage of all the visceral structures in the abdomen, such as blood-vessels, nerves, and serous membranes. In no case was rupture of a solid viscus observed. There is usually severe surgical shock. *Cases* 3, 5, and 6 fall into this group. The rupture of mesenteric vessels occurs, with the production of lesions varying from small petechiæ to large hæmatomata. In no case was actual tearing, or rupture, of the mesentery itself observed, although the large hæmatoma at the ileocæcal junction in *Case* 5 may have approximated to this. There are, in addition, submucous and subserous hæmorrhages of the bowel, with one or more circular ruptures of the intestine. The hæmorrhages may be distributed widely throughout the bowel, although they tend to occur mainly in the lower abdomen, and only one case was observed where they affected the upper portion. Rupture of the intestine, on the other hand, was strictly limited to the contents of the lower abdomen. In the small intestine it always occurred on the anti-mesenteric surface of the terminal portion of the ileum. One laceration of the large bowel was found, and that was of the sigmoid flexure at its most dependent and mobile part. Perforations may be multiple or single and also vary considerably in size.

Chiefly as a result of perforation, hæmorrhage occurs into the peritoneal cavity, and this again varies with the severity of the lesion, but it adds to the shock already present, and may complicate the clinical picture.

Type 3.—This includes those patients in whom there is injury to the bowel, but of such a degree that complete perforation has not occurred. That is to say, there is a rupture of the mucous and submucous coats only, but in some cases damage must also occur to the other coats which may later undergo necrosis with resultant perforation. This necrosis is probably also assisted by the local damage to the vascular supply. The patient may thus show early evidence of bowel injury by hæmatemesis or melæna, but his physical signs do not warrant immediate surgical intervention, although this may be urgently required later on. *Case* 7, where it was assumed that perforation occurred many hours after his injury, is a typical example. This assumption was based on the symptoms and clinical findings, for he remained well for so long, and then suddenly became acutely ill with obvious peritonitis. At operation the perforation was minute, with no pouting of the mucous membrane as in *Cases* 3, 5, and 6.

More controversial is the inclusion of *Cases* 2 and 8 in this group. In them a spreading peritonitis was found some time after the injury, but no perforation could be found at post-mortem and operation respectively. The peritonitic fluid was turbid, but non-smelling, in contrast to *Case* 7, where the fluid was already foul.

The question naturally arises: Is it possible to have a productive peritonitis going on to abscess formation, secondary to intensive bruising of the bowel, but without perforation, and did this actually occur in *Cases* 2 and 8? It is considered possible that this might occur, for the damage to the blood-supply to the intestinal wall may be such as to allow the escape of organisms outside the bowel without actual perforation. However, it did not seem probable at the time, and it is more likely that a minute perforation did occur in both these cases, and that this was missed. The late result of such a lesion, if the patient survives, will be a residual abscess, most commonly situated in the pelvis or subphrenic space.

It must be remembered that patients showing this partial damage to the bowel wall may also have damage to other organs, as we have seen in the previous types, such as mesenteric and subserous ecchymoses. Incidentally it was only in *Case* 2 that damage of the upper abdominal contents was found, for, as has already been stated, the submucous rupture of the bowel was of the hepatic flexure of the colon.

Type 4.—The remaining cases must be grouped apart from those described above, and no facts can be given as to the morbid anatomy of their lesions, for none came to post-mortem or operation. From their symptoms and physical signs, however, it seems likely that essentially their lesions were similar to those already described, varying in degree. Rupture of the mesenteric blood-vessels and ecchymoses in the bowel wall account for most of the symptoms and physical signs observed. Rupture of the mucous and submucous coats may have been present as in *Type* 3, but if so they did not proceed to perforation. It is only, however, by the occurrence of perforation, peritonitis, or abscess formation, that cases in *Type* 3 can be separated clinically and pathologically from this group of patients.

The Mechanism of the Injury.—One of the first things that became evident when these patients were surveyed was the relative preponderance of abdominal over chest injuries, in contrast to the effects of blast from bombs bursting on land. Only three of these cases showed evidence of lung involvement, *Cases* 1, 2, and 4, and they all died. It seems reasonable to assume that the lungs enclosed in the relatively rigid bony thorax would suffer less than the relatively unprotected abdominal viscera when a sudden 'water-hammer' compressive force is applied. Furthermore, all the patients were wearing air-inflated life-belts, some of the new 'Mae West' type, which must give some degree of added protection to the chest.

Where, in addition to a sudden compressive force applied to the chest, there is also an increase in abdominal pressure with a forcing up of the diaphragm, it would be expected that the bases of the lungs would be especially affected, and this indeed was noted at post-mortem, in *Case* 2.

Chest involvement is of the greatest importance. If present in association with severe intra-abdominal injury, the prognosis is very much worse, and early operative treatment is likely to be impossible.

With regard to the abdomen, some explanation must be offered as to why it was that the viscera situated in the lower abdomen were most commonly injured, and why such an injury was often on the antimesenteric surface of the intestine. From a study of these cases, it is obvious that the bowel that was ruptured was nearly always that part which actually lies normally in the pelvis. In the only case in which this was not so (*Case* 2), the bowel injury was of the hepatic flexure of the colon. It is suggested that the explosive force, hitting the abdomen, acts as a compressor, and that this compression is transmitted through the anterior abdominal wall to the contained visceral structures. The main effect of this compression is to force the contents partly upwards against the resistance of the diaphragm and partly downwards and backwards against the bony walls of the pelvis. In the pelvis the bowel meets with more resistance than above, and hence the pressure inside the bowel is further raised, producing a lesion at the weakest point, which is the antimesenteric surface. Alternatively, it may be that the explosion sets up a compression wave which passes through the abdomen, and by reaching the contents of the abdomen in the pelvis suddenly increases the pressure there. It is brought to a full stop by the bony walls of the pelvis, and, by direct trauma to the bowel, may do damage. This lesion may be a complete or only a partial perforation. *Cases* 3, 5, 6, 7, and 8 had entirely lower abdominal injury and physical signs. That this can also occur in the upper abdomen is shown by *Case* 2. *Case* 4 also had upper abdominal physical signs, but it is possible that these were due to bruising of the diaphragm and lung involvement, rather than to direct abdominal injury.

If this conception of a compressive force is accepted, it follows that the splanchnic and parasympathetic nerve plexuses are exposed to injury by compression at the same time, as are also the mesenteric blood-vessels, and that rupture of these vessels occurs either at the moment of compression, or as a result of a sudden release phenomenon immediately following the rise of pressure.

Management.—The first question that has to be answered is: Which patients require operation and which do not? Of the former group, some are too ill for operation and will die whatever is done for them. The earlier the patients are seen the more difficult is the problem, but if they are not seen until relatively late, and this will be the lot of the majority, the really serious cases will be already moribund, and most of the others will either have signs of frank peritonitis, or will be recovering.

During the first few hours after the injury it is almost impossible to say which patients will require surgical treatment, and such resuscitatory methods as are at hand should be prescribed. Blood transfusion is required for many of them. Cases of *Type* 1 are already beyond repair. Patients, also, who show signs of chest injury should be treated conservatively. For the rest, certain facts emerge as a result of the observations on this series.

After the preliminary treatment for shock and response to this treatment has occurred, the following factors influence the decision to operate. The presence of severe, unremitting, and more especially increasing abdominal pain, with tenderness and rigidity of the lower abdomen, particularly in the presence of melæna, bowel actions, and difficulty in micturition, are indications for laparotomy. The general condition and pulse-chart give little, if any, help in making the decision. The general condition, with the exception of cases of *Type* 1, may always be expected to improve in the first hour or so, and may remain satisfactory for twenty-four hours or more, to be followed often by a dramatic deterioration. A study of the pulse-charts in these cases is interesting. With one exception there was no rise in pulse-rate, and in some it even fell, in the presence of severe bowel lesions. This is most likely to occur in cases of *Type* 3 which went on to perforation, and the less severe cases of *Type* 2. Providing the general condition allows operation, it is the local condition which must always be the deciding factor.

When the symptoms and signs are of the upper abdomen, and especially when associated with signs of chest involvement, it must be quite certain that these abdominal signs are not referred from the chest before the abdomen is explored. It is only when the abdominal signs are actually increasing and it is certain that the abdominal lesion is the essential one, that it is justifiable to open the abdomen.

The remaining cases that do not present sufficient evidence for early laparotomy must still be carefully watched, for as has been shown, patients of *Type* 3 may perforate relatively late. It must be remembered that such a patient may perforate up to at least 36 hours after the injury.

It is probably also true that in some patients a delayed perforation may occur after an early one has been closed, and will account for the onset of a peritonitis causing the death of a patient who is apparently doing well.

It can be seen that the greater the injury the easier it is likely to be able to decide on the correct line of treatment. Again, the earlier a patient with ruptured bowel is operated on, the better are his chances of survival, but decision to

operate must not be taken lightly, for a patient who is operated on unnecessarily has his chances of recovery jeopardized. A patient with a perforation, on the other hand, who is denied operation will almost surely die.

It remains now to indicate the details of treatment, and of operation and post-operative management.

All patients on admission require warmth and rest. Morphia in sufficient doses should be exhibited after the patient has been examined. Intravenous fluids and blood, if available, are required for the more seriously shocked patients. Small sips of water are allowed and a half-hourly pulse-chart instituted. The urine should be tested for blood and catheterization may be required.

The patients who were operated on in this series were anæsthetized with a quick induction of C_2E_3 for the passage of an endotracheal tube and then maintained by gas and oxygen with a little ether. A midline abdominal incision is recommended, for it saves a vast amount of time, gives a good exposure, is easy to close, and heals well. Speed of operation, within reason, is essential, and the minimum amount should be done consistent with necessity. Only one operation in this series lasted more than half an hour. Perforations of the small gut, unless multiple or very gross, rarely need more than simple closure. Where possible a ruptured colon should be exteriorized, or, if this is impracticable, the bowel should be drained above the lesion, and a drain put down to the colonic suture line. The pelvis should be mopped clean of fæcal material, and the abdomen closed over a pelvic drainage tube.

The post-operative treatment is probably as important as the operation, and must be energetic. Paralytic ileus, secondary to trauma, as well as to peritonitis, is the greatest danger. Unless the general condition is extremely good after operation, intravenous fluids should be given until a suitable water balance is established. Blood will often be required and is of advantage in all cases which do not improve rapidly. Fluids by mouth need not be withheld, but should be given in small quantities, and increased as the general and local condition allow. No supplies of sulphathiazole were available on this occasion, but there is little doubt that intraperitoneal and intravenous use of the drug would have been beneficial. If paralytic ileus develops it should be treated on the usual lines. In all other respects the post-operative management is the same as for any other abdominal emergency.

SUMMARY

Sixteen cases of abdominal injury due to under-water explosion are described. Six were operated upon and four of these died. Two of the remaining ten cases died without operation.

The operation and post-mortem findings are given, and an attempt has been made to classify the pathological and clinical types. Some opinions are expressed on the management of these cases.

While it is realized that full justice has not been done to the wealth of clinical material that was presented to us, we feel that some record of our findings and opinions is indicated, for we were fortunate in being able to see so many patients of this type at the same time, and so soon after their injury. We regret that conditions did not allow of a more detailed study, both of the living and the dead.

SUMMARY OF CASES

Case 1.—Severe compression injury of abdomen. No operation. Death from shock within a few hours after injury.

Case 2.—Compression injury of abdomen and lungs. Death on sixth day without operation. A post-mortem severe lung damage. Low-grade pelvic peritonitis. Rupture of mucous membrane of colon. Death from lung injuries.

Case 3.—Signs of severe abdominal injury on admission. Operated on six hours after injury. Diffuse hæmoperitonitis. Large laceration of pelvic colon and two perforations of terminal ileum. Death eight hours after operation.

Case 4.—Physical signs of abdominal injury on admission. Operation eight hours after injury. No lesion other than ecchymoses of bowel discovered. Death thirty-six hours later from compression injury of lung.

Case 5.—Very ill on admission. Operated on ten hours after injury. Diffuse hæmoperitonitis. Two large perforations of terminal ileum sutured. Died thirty-six hours later from peritonitis.

Case 6.—Delayed onset of signs of perforation. At operation sixteen hours after injury two perforations of terminal ileum closed. These had occurred at the time of injury. Pelvic hæmoperitonitis. Recovery.

Case 7.—Perforation occurred twenty-four hours after injury. At operation a recent perforation was closed. Pelvic peritonitis present. Death six days later from peritonitis.

Case 8.—Onset of severe abdominal pain thirty-six hours after injury. At operation a pelvic peritonitis only. No perforation discovered. Recovery after formation and natural resolution of pelvic abscess.

Cases 9–16.—All presented signs of abdominal concussion on admission, but all recovered without operation ahd without complications.

CRITICAL REVIEW

WAR WOUNDS AND INJURIES OF THE CHEST

By A. TUDOR EDWARDS, London

The relatively low incidence of chest wounds admitted to ambulances and casualty clearing hospitals during the 1914–1918 war was in striking contrast to what was to be expected from the relatively large body surface exposed. Thus the chest casualties only amounted to between 3 and 4 per cent of the total wounded admitted to hospital. There has apparently been an increase in the relative incidence in more recent campaigns; Ransom (1940) reported an incidence of 10 per cent in chest casualties admitted to a base hospital in the earlier stages of the Sino-Japanese War; Trueta (1939) recorded 12·1 per cent of casualties at Barcelona in the Spanish Civil War; and chest wounds showed a proportion of 5 per cent of the casualties during the relatively recent Dieppe raid. Schrank (1942) states that on the German Eastern front chest wounds are next most most common to limb wounds in occurrence.

That these figures by no means represent the actual incidence of chest wounds is shown by records of examination of numbers of those killed upon the battlefield. Sauerbruch (1942) reported that from an examination of three hundred dead on the battlefield 37 per cent showed wounds of the chest, but whether they were killed during an attack or during trench warfare is not clear. Walker (1940, a), as a result of personal visits to battlefields, states that he was impressed by the number of soldiers killed instantaneously by small fragments entering the front of the chest, damaging the heart and origins of the major vessels and roots of lungs. Both groups of figures refer to the 1914–18 war. He also quotes Loeffler's figures of the Danish War of 1864, in which 29 per cent of 469 dead on the battlefield were wounded in the chest. In the Russo-Finnish campaign Acutin (1940) states that the Russian pathologist Ivanova carried out a survey of corpses on the battlefield which showed that 40 per cent died from chest wounds.

Analysis of wounded admitted to casualty clearing stations during 1914–18 showed that 58·51 per cent were wounded by shell and mortar fragments, 2·19 per cent by bomb and grenade, and 38·19 per cent by bullets (Walker, 1940). In over six hundred chest casualties recorded by Mann (1919) from a Canadian clearing station from January, 1916, to November, 1917, the relative incidence was rough missiles, i.e., shell, bomb, and grenade, 82·41 per cent; smooth missiles, i.e., rifle bullet and shrapnel ball, 17·3 per cent; bayonet wounds, 1·16 per cent. The variation in these figures probably represents the difference between open and trench fighting.

In both cases, the incidence of wounding by missiles of low velocity (under 600 ft. per second) is higher than those of medium (600–1200 ft. per second) or high (over 1200 ft. per second) velocity. In view of these and other figures Walker has been a strong advocate of affording the vital areas of the chest similar protection to that afforded the head by the steel helmet. In the early stages of the present war Walker advocated a protective jacket in which metal was incorporated and weighing about 14 lb. This, in spite of the fact that a large proportion of infantry in modern war is lorry-borne, means a considerable increase in weight to the already heavy equipment of the soldier. Later he suggested the insertion of a metal plate in the gas-mask case which would be over the sternal area in the "alert" position for infantry. No evidence has been published of the results of the wearing of any protective chest covering during this war.

Mortality after Removal from Battlefield.—During the 1914–18 war chest casualties ambulances, clearing stations, or base hospitals all had an appreciable mortality, but there has been a considerable fall in this mortality in successive wars. MacCormac reported a death-rate of 54·8 per cent for penetrating wounds of the chest at Sedan, and Fischer of 55·8 per cent at Metz, during the Franco-German War of 1870–71.

Neither in the South African nor in the Russo-Japanese wars did gunshot wounds of the chest provide a serious problem. In these instances the wounds were largely inflicted by small-calibre bullets, and in the former case the climate was good and the soil dry, clean, and free from contamination by pathogenic organisms. In fact, wounds of the chest were regarded as the least dangerous of the visceral wounds. Stevenson, in the South African War, without giving details of the incidence of pleural sepsis, recorded 30 deaths in 214 cases—14 per cent. The excellent results obtained by conservative treatment in South Africa were subsequently indirectly responsible for a high mortality in the earlier stages of the 1914–18 war, where expectant treatment was employed for the first eighteen months. In France the highly fertilized soil, its contamination from trench warface in which long periods of fighting took place over the same areas, the secondary contamination of the soldiers' clothing, and the larger number of lacerated wounds due to fragments of shell, mortar, or hand grenade, were all potent factors in the high incidence of sepsis which was responsible for the considerable mortality of casualties surviving to the ambulances or

casualty clearing stations. Gordon-Watson (1940), in considering 3521 chest casualties in the second army at Paschendaele during the late summer of 1917, records a mortality of 7 per cent at the field ambulances, of 15·9 per cent at the casualty clearing stations, and of 4·6 per cent at the base hospitals, i.e., a total mortality of 27·5 per cent in France. In this group 44·6 per cent of patients with sucking wounds—open pneumothorax—died, 44 per cent died after drainage for pleural infection, and 30 per cent of those not drained. Duval (1919), collecting the results of 3453 chest casualties reported by thirty-seven authors, records a 30 per cent mortality in dressing stations, 25 per cent in ambulances, and 15 per cent in hospitals.

In war so widely spread over the world as is the present conflict it will be seen that conditions may be so variable that in each area where fighting is taking place, local conditions must be taken into consideration in determining treatment. It has been demonstrated, for instance, that in much of the fighting in the Libyan campaign a more conservative attitude to the treatment of chest wounds has been possible than was adopted in this contry either for chest casualties from the Dunkirk evacuation or in the bombing raids.

In fact, pleural infection in closed hæmothoraces in Libya closely approximated the low incidence recorded for civil injuries. Littlejohn (1942) recorded 3 empyemas in 32 casualties evacuated and traced to the base, whereas Cato and Norman (1940) in a large series of civilian penetrating chest wounds noted that of the total 13·8 per cent showed definite evidence of hæmothorax and 1·4 per cent developed infection. These figures show a higher incidence of infection in civilian cases in which blood is present in the pleura (9·8 per cent) than in the above casualties in Libya (9 per cent), although the figures are so small as to be of doubtful value. It is possible that the early administration of sulphonamides aided in limiting infection in the war casualties. Boland (1936) in 1009 penetrating wounds in civilian life had an incidence of pleural and other serious infections of just below 20 per cent.

The foregoing remarks demonstrate that the problem of the treatment of chest wounds and injuries reaching hospital merits serious consideration, especially owing to their apparent increasing incidence and the fact that indiscriminate bombing includes not only the most healthy and vigorous portions of the population, but both sexes and all ages. For descriptive purposes chest injuries may be divided into two chief groups, the non-penetrating and the penetrating.

NON-PENETRATING INJURIES

The non-penetrating injuries of the chest correspond to those encountered in peace time, but owing to the widespread incidence of bombing and the number of casualties buried beneath buildings, the incidence is greater than in the last war, when burial by blown-in trenches, etc., the result of gunfire, provided the majority of such casualties. The higher incidence in the war is also partially due to the enormous mechanization of all services increasing the numbers of accidental injuries. Non-penetrating injury of the chest may vary from the minor contusion of the chest wall to the complete crush of the chest resulting in immediate death, but many of these casualties which survive fall into certain well-defined categories, and, apart from crushes in children and adolescents and blast injuries, the extent of damage to the thoracic cage gives some criterion as to the intrathoracic damage to be expected. In younger subjects, on the other hand, the resilience of the bones and cartilages of the thorax permit considerable deformity before fracture takes place and may lead to widespread intrathoracic damage with an intact chest wall.

Simple Fractures.—These fractures involving one or more ribs usually result from indirect violence, the chest being compressed and the fracture occurring on the arc of the rib between the points of compression. They are thus ' burst ' fractures, the displacement of the rib ends at the time of fracture being outwards. For this reason there is no tendency for the lung to be lacerated by the bone ends, although contusion of the lung may occur if the compressing force itself is sufficient.

The accepted treatment for these cases has been the application of overlapping layers of adhesive strapping applied during full expiration and taken over the midline in front and behind. Blades (1940) has advocated that the adhesive should be applied completely around the lower chest for unilateral fractures. The disadvantage of chest fixation is obvious, leading to stasis in the lower parts of the lung, atelectasis, and subsequent infection, particularly in older subjects. Several Italian surgeons, Latteri (1933), Rabboni (1936), and Grieco (1937), advocated and carried out the infiltration of the intercostal nerves with alcohol for the relief of pain, and another surgeon, Zoppi (1936), the daily injection of procaine for this purpose. Subsequently Harmon et al. (1942) recommended the injection of 2–3 c.c. of a solution containing 0·5 per cent procaine and 0·1 per cent eucupine hydrochloride with a small addition of adrenaline into the fracture site or sites if several ribs were fractured, but if there was difficulty in identifying the exact situation of the hæmatoma, double the quantity of the solution was injected into the surrounding area. Injection on one occasion was often sufficient, but a second injection was required in one to four days in a quarter of the cases. Smith (1942) has substituted a nupercain solution (1–1000) for that employed by Harmon with equally satisfactory results, using 5 c.c. into the fracture and 5 c.c. into surrounding tissues for each fracture. These methods are worthy of more extended trial in this group of fractures.

" Stove-in " Chest.—This condition results from a relatively localized direct injury and consists of anterior and posterior fractures of several ribs. A segment of the chest wall, therefore, becomes relatively mobile and shows paradoxical movement, being sucked in during inspiration and blown out during expiration. The effect is somewhat similar to a large ' open pneumothorax ' and causes the same cardio-respiratory embarrassment and considerable shock, and may be accompanied by contusion or laceration of the lung, demonstrable radiologically by hæmatoma formation, pneumothorax, or hæmothorax, and localized or widespread surgical emphysema. In these cases immobilization of the chest wall by overlapping layers of adhesive strapping rapidly improves the grave condition, and the administration of high concentrations of oxygen by the Boothby mask is invaluable. Evidence of serious intrathoracic bleeding from larger vessels may necessitate blood transfusion and symptoms of hæmorrhage continuing affords one of the rare indications for open operation.

Associated Fractures.—Other injuries such as fractures of scapula and clavicle, and dislocation or fracture of the sternum are occasionally found in association with crush injuries. Another injury which may pass unsuspected, unless the spine is X-rayed, is compression fracture of one or more vertebræ.

Traumatic Asphyxia occasionally results from sudden short compression of the chest. It is followed by a dark blue discoloration of the skin of the face, neck, upper chest, shoulders, and upper arms. Areas of normal looking skin may be seen corresponding to areas of pressure by the collar. Retinal hæmorrhages occasionally occur and may be followed by optic atrophy, but subconjunctival hæmorrhages are usually present. The condition is due to back pressure along the valveless veins of the head and neck, which become temporarily paralysed.

Extravasation of blood into the tissues occurs in some cases, and fading either occurs gradually or by the stages associated with an ordinary bruise. No specific treatment is possible, but examination should be made for associated injuries.

Injuries of the Lung and Pleura.—Apart from damage to arteries and veins of the chest wall, which in the larger vessels prove rapidly fatal, contusions and lacerations of the lung are relatively common. Definite hæmatomas may be seen showing larger defined or multiple smaller diffuse shadows in the lung on radiological examination and a greater or less quantity of blood may be found in the pleura. Such cases of hæmothorax should be treated on similar lines to those caused by closed penetrating wounds.

Lobar or massive collapse, probably due to blood or thick mucus in the bronchi and to the inability of such patients to cough, may be found in the affected or contralateral lung. Bradford (1918), in reviewing cases of pulmonary collapse occurring during the 1914–18 war, considered the cause of the condition " the result of immobility and retraction of the chest wall and diaphragm, possibly due to reflex nervous origin." The raised diaphragm and retracted chest wall are more probably the result than the cause of the collapse.

Surgical emphysema over a localized area is relatively common in non-penetrating injuries; occasionally it is more widely spread, passing up in the muscle planes and subcutaneous tissues to the neck and face. Although uncomfortable for the patient it rarely requires treatment as the major portion of the air has already escaped from the lung into the pleura soon after injury, and as a result of coughing secondarily involves the superficial chest-wall tissues and absorption is rapid. When minor or larger bronchi are opened the escape of air into the pleura may be serious and lead to a ' tension pneumothorax,' with acute symptoms of mediastinal displacement, cyanosis, hyperpnœa, and accelerated pulse, which will require urgent relief, the associated surgical emphysema steadily increasing until the pleural tension is relieved. Tension pneumothorax occasionally results from tearing of a pleural adhesion due to previous disease, the air escaping into the pleura during inspiration and the superficial opening being unable to close in the normal way by collapse of the lung. Treatment is similar to this complication in penetrating injuries.

Mediastinal emphysema is a much more serious although rare complication of chest injury. It results from damage to larger bronchi or the trachea, the air passing up in the mediastinal tissue to escape through the upper aperture of the thorax into the deep and superficial tissues of the neck. Partial obstruction to the larger veins in the mediastinum may result in some cyanosis of the head and face and difficulties in respiration and swallowing are encountered. Frey (1940) states that it occurs more frequently on the third or fourth day after injury. In some cases the mediastinal pleura is torn at the same time and tension pneumothorax is associated. Treatment by incision at the suprasternal notch, the introduction of a subcutaneous cannula and, where intrapleural communication is also present, aspiration or intercostal drainage of the pleural cavity have all been advocated.

Late complications in the lung and pleura are the result of (1) infection, viz., pulmonary abscess from an infected hæmatoma or area of non-aerated atelectasis, and pyothorax from an infected hæmothorax; and (2) deformity of the chest wall. The realization of such possibilities as infection should be constantly borne in mind and the early prophylactic value of sulphonamides realized. Repeated review of the patient, including radiological examination, will often anticipate the establishment of serious complications and lead to their control in the early stages.

Cardiac Injuries.—Little attention has been paid in the past to cardiac injuries following crush injuries, but Warburg (1940) has recently collected

more than 250 cases from the literature. The majority of the patients were past middle life, although many cases in children have been recorded. The commonest results are: (1) Pericardial hæmorrhage or fibrinous exudate, and this group has a good prognosis; (2) Auriculo-ventricular block in which symptoms occur soon after injury and a proportion of whom make a good recovery; (3) A group in which there is myocardial injury with various changes in the electrocardiogram; (4) Those with anginal symptoms which probably result from vascular damage. A quarter of the cases showed auricular fibrillation. In his own cases, 10 in number, Warburg reported 2 complete recoveries, 2 deaths, and 6 with evidence of cardiac impairment. The important points are a careful evaluation of the history and examination with the electrocardiograph. Anderson (1940) states that very few cardiac injuries are recognized during life. He records a case of valvular injury and myocardial contusion which recovered with minimal disability. Secondary softening of contused cardiac muscle may lead to rupture in the second week, and he considers it an advantage if the pericardium is torn at the time of injury as urgent symptoms of cardiac compression are absent, the blood escaping into mediastinum or pleura. He advocates morphine in the early stages, aspiration of the pericardium if excessive fluid is present, and absolute rest for six to eight weeks.

It is obvious that the heart may be injured from penetration by fragments of ribs or portions of fractured sternum, but it is not so widely recognized that serious injury may occur from compression of the heart between the sternum and the vertebral column.

The question of the value of surgical treatment for cardiac injuries due to crush injury has not yet been settled, but it is interesting that Bright and Beck considered that 25 per cent of an autopsy series analysed by them presented " opportunities for treatment that were not utilized " ; in the vast majority rupture of the heart was the most frequent lesion. More careful and regular cardiac examination, including electrocardiographic studies, when indicated, should in future result from an increasing realization of the fact that certain cardiac lesions result from crush injury, that complete recovery may depend upon careful assessment and treatment, that occasionally pericardial aspiration may save lives, and that rarely open operation may be indicated.

Blast Injuries.—Although reference was made to deaths of soldiers on the battlefields in the 1914–18 war associated with blood-stained fluid in the mouth and nose and without obvious gross injury to the chest wall, the pathology was not generally recognized. The increasing number of these cases as a result of widespread and indiscriminate bombing has led to much greater interest in their causation and pathology.

Zuckermann (1940, 1941) has carried out considerable experimental work on this subject, exposing various animals to the blast of 70 lb. of high explosive. None of those animals died which were at a greater distance than 18 ft. from the explosion, and none sustained damage at a distance of over 50 ft. By the nature of the experiment, superficial and deep injury to the chest wall and penetration were prevented. The common pathological findings were those of bilateral pulmonary hæmorrhages in the survivors, and in those that were killed by the explosion blood was also present in the trachea and bronchi. Radiological examination of survivors showed pulmonary lesions, which were in some cases complicated by atelectasis and consolidation. The lesions could be prevented in animals whose bodies were clothed in thick layers of sorbo rubber. As a result of this work, Zuckermann concluded that it is the pressure component of the blast which by its impaction on the chest wall bruises the lung.

Krohn et al. (1942) have shown experimentally that after exposure to blast there is an immediate fall in blood-pressure varying in extent and duration with the peak blast pressure. Prolonged and great increase in the respiratory rate is present in surviving animals and is due to stimulation of deflative nerve-endings and increased sensitivity of stretch-endings to expansion of the lungs and not to chemical changes affecting the respiratory centre or to direct blast effect on the medulla.

Dean, Thomas, and Allison (1940) have stressed the disproportion between the frequency of chest symptoms and physical signs, as in their series in which only 6 patients complained of chest symptoms there were physical signs in 16 and radiological lesions demonstrable in 14 patients. In autopsy cases hæmorrhages are found in the intercostal spaces, scattered throughout the lung or lungs, but especially marked at the lower lung fringes.

Hadfield and Christie (1941) have pointed out that bleeding may continue, as shown by the fact that patients who died after several days showed much larger hæmorrhages than those killed quickly, and these findings indicate the danger of patients with blast injuries being transported early. Osborne (1941) suggests that old age, rigidity of chest wall, obesity, and thick clothing all diminish the risk of blast injury and that artificial respiration will increase the damage to the lung. In his opinion much patchy atelectasis results from release of mucus into the bronchial tubes by rupture of the goblet cells in the bronchial mucosa. Hadfield (1941) has drawn attention to the frequency of associated carbon-monoxide poisoning. In autopsy on patients thought to have died of blast, 50 per cent showed multiple bilateral hæmorrhages and a quarter of these showed between 50 and 75 per cent saturation of the blood with carbon monoxide. Deaths in some others were due not to blast but to compression asphyxia, asphyxia due to inhalation of plaster or brick dust, severe internal trauma, or advanced medical disease.

O'Reilly and Gloyne (1941) describe the main symptoms as grave shock, prostration and restlessness, respiratory difficulty, and chest pain. Cyanosis in greater or lesser degree is a constant feature, and hæmoptysis often occurs. They noted two types of pain : deep central pain which may be due to mediastinal hæmorrhage ; and chest wall and abdominal pain, the result of subpleural bleeding into the intercostal spaces.

Williams (1942) has defined differences between the effects of blast in water and air, and points out that injury may be sustained over much greater distances in the former ; that the protection of the chest by sorbo rubber is not so effective as abdominal protection in preventing lung damage, i.e., the upthrust of the diaphragm via the abdomen must be equally if not more dangerous.

In blast injury in water the usual area of the abdominal cavity involved if visceral perforation occurs is the lower half. Signs are therefore concentrated there. Rigidity and tenderness of the upper abdomen usually indicate blast injury of the lung and not an intra-abdominal lesion.

All observers are agreed about the radiological signs, which show multiple shadows or mottling throughout one or both lungs, that they appear early, and are due to alveolar and interstitial hæmorrhages.

The dangers of general inhalation anæsthesia in the presence of blast injury have been stressed by Roberts (1940), O'Reilly and Gloyne (1941), and others, but Williams (1942) advocates gas and oxygen preceded by pentothal or evipan. As the abdominal rigidity which is common in blast injuries may be taken to indicate an abdominal lesion, this point is important and local anæsthesia would appear to be the anæsthetic of choice for any essential operation in the presence of blast injury to the lungs. Williams also states that spinal anæsthesia is contra-indicated.

The accepted treatment for the lung condition consists of rest, warmth, morphia, and oxygen administration. The value of blood and plasma transfusions is debatable (Christie and Hadfield, 1941, have even advocated venesection for the pulmonary congestion), but as secondary infection may result in a proportion of patients the early prophylactic use of sulphonamides is advised.

In mild cases the clearing of the lung picture is often complete in about a fortnight.

PENETRATING WOUNDS

Wounds in which penetration of the pleural cavity results produce great variation. Thus, perforation of the chest by a bullet which does not involve bone often give rise to little or no disturbance. The superficial wounds heal rapidly without suppuration and in some cases lung injury may consist of a small hæmatoma along the track of the missile in the lung with or without a small hæmothorax. In other cases, particularly those with wounds due to large shell or bomb fragments, widespread laceration occurs, even amounting to a considerable loss of chest wall with a large opening permitting communication between the pleura and the external air. The majority of these die early, but a proportion survive to reach hospital. Jolly points out that the prognosis is better for antero-posterior than for transverse wounds and for wounds of the middle zone of the hemithorax than those at the apex or base.

Penetrating wounds, in contrast to non-penetrating wounds, require operation in a large percentage either early or late. Gordon-Watson (1940) states that 40 per cent of chest casualties admitted to casualty clearing stations in 1917 were submitted to early operation.

Apart from those requiring operation soon after arrival at hospital, two groups of chest casualties necessitate urgent treatment in forward areas if they are to survive long enough to reach hospital.

Tension Pneumothorax.—This condition arises from the escape of air into the pleura from the respiratory tract following wounding of the larger or smaller bronchioles, rarely from laceration of the lung tissue. It occurs during inspiration and as the air is unable to pass back on expiration the result is a gradual accumulation of air in the pleura which first collapses the lung and later displaces the mediastinum with its contained structures. When the air escapes into the chest wall surgical emphysems may be extensive.

Tension pneumothorax causes increasing dyspnœa, cyanosis, and restlessness, and is easily diagnosed by hyper-resonance, absence of breath-sounds, and displacement of the trachea in the suprasternal notch and of the cardiac apex beat to the opposite side.

The majority of British chest surgeons advise the insertion of a large-bore serum needle into the second intercostal space in front and aspirating or permitting air to escape through a connecting tube to a ' water-seal ' bottle. De Bakey (1942) advocates the insertion of a small intercostal catheter attached to the same system, while Zenker (1942) advises the use of an intercostal catheter, to the outer end of which a perforated finger-cot is attached.

Open Pneumothorax.—Free communication between the external air and the pleural cavity is associated with considerable embarrassment of both respiratory and cardiovascular systems. The severity of the effects depends upon the size of the opening and whether the track is direct or oblique. In some cases, the obliquity of the track may prevent the condition being recognized until movement of the patient results in a gush of blood-stained fluid mixed with air from the wound.

In every case closure either temporary or permanent results in rapid and often dramatic improvement in the patient's condition.

When possible, the ideal treatment consists in early and complete excision of the wound and its immediate suture in layers after evacuation of blood and any easily removed foreign bodies in

lung and pleura, and air-tight drainage of the pleura for forty-eight hours through a separate opening in the lower posterior part of the chest. This is rarely possible, and temporizing measures have to be adopted. Barrett (1940) and other British thoracic surgeons advocate temporary closure by covering the wound with a pad consisting of a piece of mackintosh tissue, to one side of which several layers of vaseline gauze have been sewn. Adhesive strapping is then applied. Littlejohn (1942), working under special conditions in Libya, advises the use of deep sutures taking in all layers of the chest wall, and in spite of non-excision of ragged or torn wound edges, healing was found to be generally satisfactory. In his view dressing and packing of the wound are unsatisfactory as it tends to work loose on movement. The Russian surgeons, Linberg (1940) and Acutin (1940) advocate closure of the muscles and fascia with one layer of catgut sutures, avoiding skin suture to prevent surgical emphysema and spread of infection. In all cases of wide open pneumothorax Linberg advises fixation of the lung in the chest wall by suture, a method also advocated by von Haberer (1942). This does not appear to be a very satisfactory procedure, and if facilities are available for such operations it would appear advisable to use adjacent flaps of muscle to enable closure to be attained, but neither of these methods is possible further forward than the field hospital nearest the fighting. Zenker (1942) and Wolff (1942), other German surgeons, advise the use of dressing and adhesive strapping.

It would appear that the methods which are suitable in one area may not be applicable in another, although the application of an occlusive dressing and properly applied overlapping strapping over a wide area would appear to be the simplest method. The previous application of sulphonamides to the wound might delay infection and permit later excision. Apart from control of continuous bleeding in the chest wall, actual packing of the wound is probably inadvisable as further tissues are exposed to potential infection.

As soon as patients who have had temporary closure performed are resuscitated in hospital they should be submitted to full and adequate excision of the area involved if infection of the wound is not already established. In others, the wound may already be infected on arrival at hospital, and the chance of primary union following excision be negligible. These patients should be treated on the lines of the temporary closure. All dead tissue, loose fragments of bone, and foreign bodies should be removed from the wound but no attempt made at excision. The wound may then be filled with zinc peroxide in oil and covered by a dressing and overlapping layers of strapping. The pleura is drained by a low-placed intercostal tube and, when available, suction may be applied, but in any case as the aim is to encourage rapid expansion of the lung and adhesion to the chest wall, drainage must be airtight. In some cases, the wound may be treated by secondary suture after a few days.

Indications for Early Operation.—Judging from the experience of the 1914–18 war, a considerable proportion, probably the vast majority, of shell and bomb wounds were submitted to open operation during 1917–18. This resulted from a review of the high mortality-rate which occurred during the early war period when conservative measures were employed and operation was reserved for the treatment of established infection. Gask (1919), in advocating early operation for chest wounds, emphasized that the most important points were the prevention of infection by the early mechanical cleansing of the wound, both of the chest wall and of the injured viscera, the evacuation of all foreign bodies and of effused blood from the pleural cavity, the repair or suture of the damaged lung, and the closure of the chest cavity by suture. Price Thomas (1940) stated the indications as: (1) Open sucking wounds, i.e., with open pneumothorax; (2) Hæmorrhage which is overt and progressive; (3) Hæmothorax with retained foreign body; (4) Hæmothorax where there is reason to suppose other structures than the lung—such as the pericardium and the diaphragm—have been injured; (5) Hæmothorax with massive clot in the pleural cavity (later operation).

Linberg (1940) divides chest casualties into four groups: (1) Those not needing operation; (2) Those needing immediate operation; (3) Indefinite; and (4) Very seriously wounded needing special nursing.

Group 1 includes (*a*) oblique penetrating wounds without raising of pulse or respiratory rates, perhaps with small hæmo- or pneumothorax; and (*b*) cut or contused surface wounds. Group 2 includes (*a*) non-penetrating wounds requiring primary excision within 6–12 hours to prevent secondary extension of infection into the pleural cavity; (*b*) penetrating wounds with extensive open or valvular pneumothorax, and progressive hæmothorax; (*c*) suckling pneumothorax and open pneumothorax due often to glancing wounds by shell splinters; (*d*) pressure or tension pneumothorax, relieved by trocar, usually complicated by surgical emphysema; (*e*) thoraco-abdominal wounds. Group 3 includes (*a*) slowly increasing hæmothorax; (*b*) closed pneumothorax; (*c*) chest wounds without exit (blind). Group 4 includes the worst cases with large or multiple wounds, which are of bad prognosis, and after anti-shock measures, i.e., when the condition permits, the wound edges should be excised and the lung should be sutured to the wound edges.

The indications for early operations given by these authors are those generally accepted by chest surgeons in this country and the only doubtful indication is that of hæmothorax with a foreign body. There can be no doubt that healing is as good and infection in the pleura not appreciably increased if small foreign bodies up

to the size of a pea as seen radiologically are left without operation, and a large proportion of foreign bodies of larger size can be left for late operation with little or no increase in the risks of infection, if the hæmothorax is adequately treated. In the absence of an experienced chest surgeon it is probably safer that conservative measures be adopted in the early stages when the size of the foreign body appears to be the sole indication for operation, as in the presence of a large foreign body other indications, such as open pneumothorax, are almost invariably present. As Roberts and Tubbs (1941) have stated, the inexperienced surgeon should err on the side of conservatism.

With regard to continuous intrapleural bleeding, the chief means of assessment is by removal of specimens in which hæmoglobin estimations are carried out and by the general signs of internal hæmorrhage. Dilution by the pleural exudate is rapid unless bleeding is continuing. Zenker (1942) states that if blood withdrawn by aspiration does not clot it can be assumed that no fresh bleeding has occurred for five hours, which he explains by stating that the serous pleural effusion dilutes the blood and chest movements cause defibrination. The converse is certainly not true, as hæmothorax fluid aspirated 3 to 4 days after wounding will occasionally clot. Littlejohn (1942) has drawn attention to the fact that in occasional cases pleural exudate is poured out very rapidly and may lead to acute dyspnœa in 12 to 18 hours, which condition is equally rapidly relieved by immediate aspiration. This surgeon is averse to operation for the removal of foreign bodies in forward hospitals.

The technique of operations has been described in numerous publications, and it only remains to emphasize the advantage of performing thoracotomy, where possible, through the site of the excised wound, which is enlarged, rather than through a fresh incision, although the latter may be essential in wounds in the upper chest if sufficient exposure is to be obtained.

Another point of interest up to the present in the literature is the rare necessity for performing lobectomy or larger lung resections. The resection of small portions of damaged lung is fairly common. In civilian gunshot wounds two cases of lobectomy have been reported by Monod (1941) and one of resection of the whole lung by Brodkin (1941). All these cases were due to injury to large hilar veins and none would probably have reached hospital alive under war conditions.

The value of temporary airtight drainage of the chest after thoracotomy is accepted by most thoracic surgeons, but in almost every case a separate opening in the lower chest is advocated. The only exception is Moorhead (1942), who in the casualties at Pearl Harbour advised drainage of the pleura following excision of the wound and its tight closure around an indwelling tube. In the casualties at Pearl Harbour the number of chest wounds is not given, but apparently no empyemas occurred. Moorhead states that conditions were particularly favourable, and the excellent results in all types of wounds are partially ascribed to these factors: (1) Early receipt of the wounded; (2) Climatic conditions; (3) Early hour of the attack—men were clean and not battleworn; (4) Few flies; (5) Early use of sulphonamide drugs. The total mortality of all wounded submitted to operation was 3·3 per cent. Drainage through the excised wound would appear to have the following disadvantages: (1) The increased risk of the sutured wound breaking down; (2) The difficulty of getting complete sealing of the wound by pleural adhesion after removal of the tube, especially when removed in forty-eight hours, as it should be if infection is not to spread along the tube track into the pleura; (3) The site of the excised wound is unlikely to be the optimum point for drainage. The advantage of separate intercostal basal drainage after thoracotomy is that it permits evacuation of air and pleural effusion and hence diminishes the risk of disruption of the sutured wound, a cause of considerable mortality and morbidity in former wars. Subsequent regular aspiration is essential.

ABDOMINO-THORACIC WOUNDS

These comprise a serious group of injuries, the most severe being the tangential wounds of the left costal margin, often associated with prolapse of viscera into the wound. Mortality is higher in patients with associated perforation of the hollow viscera, stomach, upper small intestine, and colon. The following express the views of Gordon-Taylor (1941) on abdomino-thoracic wounds; (1) In many traversing abdomino-thoracic wounds of the right side due to bullets or bomb fragments, no immediate surgical treatment is required in the absence of gross damage to the trunk wall provided the track does not suggest compromise of the cœlom, signs of internal hæmorrhage, or damage to hollow viscus. (2) A small fragment remaining after a right abdomino-thoracic wound, unless easily accessible, should be left alone. (3) An open thoracic wound takes precedence of abdominal or other wounds in treatment. (4) On the left side an abdomino-thoracic wound should be approached through the chest and transphrenic access to the abdomen employed. (5) If the thoracic injury appears insignificant and that of the abdomen severe, the abdominal route should be chosen. (6) The track of the missile as inferred, or by X-ray examination, may warrant expectant treatment.

These indications cover most of such injuries, but the value of suture of the diaphragm, after phrenic crush, above the area of penetration so as to exclude the pleural cavity from the abdomen, especially in tangential wounds, is not emphasized, and is a most useful measure when there is much loss of tissue. The second point not mentioned is the value of several radiological examinations during convalescence and later after injury to eliminate the possibility of diaphragmatic hernia

when it is suspected that a small missile might have perforated the left diaphragm and when no indication was apparent for operation at the time of wounding. It is only rarely justifiable to extend a thoracotomy incision down into the abdomen by dividing the costal margin.

HÆMOTHORAX

The accumulation of blood and effused serous fluid in the pleura constitutes a hæmothorax. It follows non-penetrating wounds, closed penetrating wounds, and closure of open pneumothorax, or after thoracotomy for gunshot wounds.

Hæmorrhage may occur from the lung or from vessels of the chest wall, but in the larger hæmorrhages bleeding from the latter is probably largely responsible.

Hæmothorax is the most frequent complication of wounds and injuries of the chest, and is associated with greater or lesser degrees of hæmoptysis in about 75 per cent where penetration of the chest has occurred.

In civil life the proportion of patients with penetrating wounds of the chest which develop hæmothorax varies between 25 per cent (Boland, 1936) and 37 per cent (Elkin, 1936), whereas in battle casualties the proportion is about 80 per cent (Ryle, 1940). Apart from the increased incidence of hæmothorax, the rate of infection is higher in war casualties. The tendency in the United States, where the larger series of penetrating injuries of the chest have been recorded under peace conditions, is to treat cases of hæmothorax conservatively—the infection rate is low, 1·4 per cent (Elkin and Harris, 1941) and the total mortality in the neighbourhood of 6 per cent.

The rate of infection in penetrating wounds in the 1914–18 war as stated by Bradford and Elliott (1916) was 37 per cent in 170 cases. In a group of 204 cases of hæmothorax resulting from bombing in this country recorded by the reviewer, there were 126 cases of hæmothorax secondary to penetrating or perforating wounds. Of this number 21·9 per cent became infected. Matsyev (1940) reported on 182 cases of hæmothorax admitted to a special unit for war injuries of the chest in which 2 per cent of closed cases became infected and 16 per cent of cases in which the chest wound had been closed by suture.

Livingstone (1940) reported that 30 per cent of 115 cases of hæmothorax became infected. Edwards and Morriston Davies (1940) record 17 per cent infections in a small series of hæmothorax cases due to bomb injuries. Littlejohn (1942), reporting on chest wounds in Libya, traced 32 cases to the base, in which 3 developed empyema — 9 per cent.

Although in the past the risk of infection of a hæmothorax in penetrating wounds was much greater in war than in peace, the discrepancy is not so obvious at the present time. On the other hand, considerable variation is apparent in different groups of battle casualties and must depend upon local conditions as well as upon the treatment employed. The diagnosis of hæmothorax in closed injuries is usually obvious from the well-recognized signs of pleural effusion and the ground-glass appearance in radiographs. The absence of clotting of the blood in hæmothorax has been subject to many explanations. In all cases which are explored, a certain number of clots are almost invariably found, especially in the costophrenic areas. It has been suggested that when the bleeding is rapid clotting will occur, but when it is slow and effusion from the pleural membranes dilutes the blood, the chest movements defibrinate it and clotting does not occur. The presence of air in addition to blood is also stated to be a factor in increasing the probability of clotting.

Rose Bradford (1917) stated that " the bloody fluid in hæmothorax contains no fibrinogen and that though it resembles blood to the eye clotting has really taken place and that it is in reality defibrinated blood."

That this explanation is not completely adequate is shown by the fact that in a proportion of hæmothorax cases the blood and effusion, which is fluid in the pleura and which is easily evacuated through a needle with a relatively small lumen, may clot within a few minutes after withdrawal. The treatment of hæmothorax has in view (1) the early evacuation of the fluid to relieve intrapleural pressure, (2) the removal of the blood which is an excellent culture medium for organisms, (3) the securing of early re-expansion of the lung and thereby limitation of the area of infection should such supervene, (4) prevention of massive clotting, (5) limitation of the period of invalidism. The reviewer (1943) in the above-mentioned series of 204 cases of hæmothorax recorded infection of 12·5 per cent of those aspirated within 48 hours compared with 21·6 per cent in those in whom aspiration was delayed beyond this time. Hoyle (1940) states that in the 1914–18 war traumatic hæmothorax which remained sterile had practically no mortality after the first two days, and the average period of invalidism was three months. Of this group 5 per cent were permanently invalided. Infection occurred in 33 per cent and the mortality-rate in this group approached 50 per cent and convalescence was long and tedious in the survivors, many of whom kept the legacy of a collapsed lung and rigid thorax. Apart from infection, a small number of untreated patients in whom the hæmothorax does not completely absorb develop a localized collection of fluid which causes chest rigidity, the blood gradually being replaced by fluid loaded with cholesterin crystals, and the walls of the encysted pocket may later become calcified. Should infection supervene in the course of years, the condition is most difficult to cure. For all these reasons evacuation of blood in all cases of hæmothorax is indicated as early as is safe. Almost all British authorities agree about the desirability of this measure and that the risk of reactionary hæmorrhage from the lung is small. Thomson (1940) advocates non-intervention in hæmothorax and suggests that

there is a risk of introducing infection, and Stuppell goes to the other extreme in advising thoracotomy for all cases of closed hæmothorax. Linberg (1940), Matsyef (1940), Acutin (1940), among the Russian surgeons, state there is no argument in defence of leaving blood in the pleural cavity except for the problematical danger of reactionary hæmorrhage, which no one has observed and for which in any case there is no factual evidence. Sauerbruch (1942), Zenker (1942), Franke (1942), and other German surgeons likewise favour early aspiration. Nixon (1941, b) holds the same views and states that in a wide experience he has seen only 5 cases of recurrent hæmorrhage and that the signs of increasing pleural effusion after twenty-four to thirty-six hours are scarcely ever due to active hæmorrhage.

The advantages and disadvantages of air replacement of the hæmothorax fluid have been widely discussed. The fear of reactionary hæmorrhage from the expanding lung has been the main indication. This risk has been much overstressed, as in almost all cases bleeding from the lung wound probably ceases by hæmatoma formation after twenty-four hours, and if it continues longer is due to injury of vessels of the chest wall. On the other hand, the introduction of sufficient air will permit full aspiration of the effusion without discomfort to the patient and would appear to have advantages at the first aspiration. A disadvantage has been pointed out by Roberts and Tubbs (1941) that the maintenance of a large pneumothorax will lead to a considerable empyema cavity should infection supervene.

The occurrence of clotting in an apparently sterile hæmothorax has been recorded on many occasions. In such cases early aspiration has been neglected, and it is essential to turn out the clot by a small intercostal incision, suture the chest wall, and regularly aspirate the secondary effusion. It has been suggested that all cases of late clotting are due to low-grade sepsis.

Infection of a Hæmothorax usually becomes evident between the fourth and seventh day. In gas infections, *B. welchii*, etc., the onset may occur relatively suddenly and acute symptoms of tension pneumothorax with acute dyspnœa, cyanosis, and rapid pulse result in a few hours. Gas gangrene of the lung has not been described and infection arises in the fibrin and blood-clot in the hæmothorax. The uninfected hæmothorax is usually associated with some pyrexia, often as high as 101°, but the pulse is relatively slow unless the hæmorrhage has been extensive. At the onset of infection the rise in pulse-rate is the most significant sign, but if aspiration is carried out regularly, bacteriological examination is made of the fluid on each occasion. Occasionally, as Tubbs points out, infection is present in fibrin and no organisms are found in the fluid aspirated.

Authorities in all countries are impressed with the serious results of total empyema and therefore from the earliest moment after wounding every effort is made to encourage full pulmonary expansion. For this reason all open drainage of the pleural cavity when infection is evident must be avoided, as the lung will collapse and in addition to toxæmia the patient will have the added disadvantage of an open pneumothorax.

It is difficult in the presence of serious pleural infection, which will extend to the chest wall, to maintain airtight drainage after rib resection. Two alternatives remain—drainage by the intercostal introduction of a full-stretched Malecot's tube or by repeated aspiration. Nixon (1941, a), Hoyle (1940), and many others advocate repeated aspiration until the infection is localized. Edwards and Davies (1940) used intercostal drainage and irrigation with dilute azochloramide solution. The reviewer prefers aspiration, but intercostal drainage with a careful sealing at the junction of chest wall and tube may be advisable if difficulty is encountered with aspiration. Among German surgeons, Sauerbruch (1942) insists on the advantages of early aspiration and delaying drainage until localization occurs.

Anaerobic infection of the pleura was regarded as of serious import in the 1914–18 war and open drainage was promptly employed with a high mortality. In the relatively few cases which have occurred in this country during raiding the results from aspiration, associated with preliminary incision of the chest wall to prevent spread of infection there, have been satisfactory. Linberg (1940), in the Russo-Finnish campaign, found the course of anaerobic infection of the chest wall and of the pleura to be quite favourable.

It is probable that if early and repeated aspirations are carried out as a routine the incidence and virulence of anaerobic infections will be diminished.

Whether aspiration or intercostal drainage is employed, unless rib resection and adequate drainage are employed as soon as localization occurs, chronic empyema will result in the majority of patients.

Thoracic surgeons in this country are insistent on the value of respiratory exercises in the complete and rapid rehabilitation of patients with chest wounds and of the complete obliteration of the empyema cavity before removal of the tube if recurrence is to be avoided, a point which Brock (1941) has emphasized,

LATE REMOVAL OF FOREIGN BODIES

In view of the late complications up to twenty years after wounding which result from retention of large foreign bodies, e.g., pulmonary abscess, bronchiectasis, hæmoptysis, etc., the larger foreign bodies should be removed at the optimum time after healing. If sepsis has supervened, the pleural sinus may lead down to the foreign body and healing will not occur until its removal has been effected. Operation in such cases should be delayed over a period of weeks until the empyema cavity fails to diminish in size unless such emergencies as secondary hæmorrhage

necessitate earlier operation. When healing has resulted without sepsis the fifth or sixth week after injury appears the most satisfactory time for foreign-body removal, although if the chest has to be opened earlier for such conditions as a clotted hæmothorax it should be removed at the same time. Careful radiological localization is essential and intercostal incision often sufficient. Petit de la Villeon (1940) recommends the removal of all foreign bodies irrespective of size by a special technique. At the end of one month the foreign body is localized by X rays and the nearest point to the foreign body marked on the skin. A small skin incision is made and a special pair of narrow grasping forceps is introduced between the ribs. The approach of the forceps to the foreign body is controlled by the X-ray screen, and it is stated that the capsule or piece of clothing is often extracted with the foreign body. This method should not be employed for foreign bodies near the pericardium, hilum, or mediastinum. Although the method sounds crude and dangerous, and portions of clothing carried in with the missile must often be left, the fact that only 3 deaths occurred in 1000 operations is striking. Littlejohn (1942) advises removal of foreign bodies two weeks after wounding, and other writers advocate non-removal until symptoms indicate.

The removal of all large irregular foreign bodies from the lung either early or delayed has been strongly advocated by Sauerbruch (1941) and Konjetzny (1939), a view in keeping with the opinion of chest surgeons in this country. The prevention of secondary changes in the lung is of considerable importance. The former reports 3 fatalities among 45 patients and the latter 1 fatality in 37 patients submitted to operation after secondary changes had taken place.

ATELECTASIS IN CHEST INJURIES

One or two observations have been made earlier in this paper on atelectasis or collapse in non-penetrating wounds. Lobular, lobar, or total collapse of one lung may result from penetrating wounds. Lobular or patchy collapse is relatively common and probably accounts for the high position of the diaphragm noted by almost all observers associated with penetrating wounds producing hæmo- or hæmo-pneumo-thorax.

Other explanations have been put forward for the high position of the diaphragm such as protective spasm by Littlejohn (1942), but this should result in a low diaphragm level, and a concussion of the phrenic nerve leading to temporary phrenic paralysis by other writers. Pulmonary atelectasis or collapse may occur in the contralateral lung, and in all cases is probably the result of bronchial obstruction due to the presence of blood or mucus or both in a lung in which evacuation has been limited by the pain induced by coughing.

Alteration in posture with gentle percussion on the area involved when possible is the most simple method of inducing early resolution by re-aeration. Bronchoscopic aspiration, except in the very early stages of either lobar or total unilateral collapse, is unlikely to be beneficial. In the patchy type it is useless.

In a proportion of patients with localized or lobular collapse, resolution may be delayed and suppuration take place, and in view of this, prophylactic treatment by sulphonamides should be instituted early.

THE VALUE OF RADIOLOGY

Too much emphasis cannot be placed on the necessity for the use of X rays in diagnosis in chest injuries in war. Physical signs can be most deceptive and accurate diagnosis becomes more and more dependent upon radiographs for the exact information which is essential in the control of chest wounds and injuries from the most advanced hospital until the patient is convalescent. Many medical men in the past have stressed the difficulties rather than the advantages, and it is not surprising that all reports have shown the reliance placed upon this diagnostic measure. In only one instance in the available literature has X-ray examination at the first hospital where apparatus is available been considered inadvisable. With the modern transportable apparatus less discomfort is caused to the patient by radiological examination than by attempts at full clinical examination of the back of the chest. More useful information is given if the patient is radiographed in the sitting than in the lying posture, and as the former is the most comfortable unless shock is very considerable, it entails minimum movement to slide the film cassette behind the patient. Lateral exposures are always required. Fluid levels, the situation of air or fluid in pleura, mediastinum, or pericardium, displacements of the mediastinum, pulmonary collapse, and localization of opaque foreign bodies can all be determined by radiological examination.

WOUNDS OF HEART AND PERICARDIUM

The number of casualties surviving gunshot wounds of the heart and pericardium was small in the 1914–18 war, and of the casualties due to bombing in this country only 2 cases are known to the reviewer—one of wounding of the pericardium by a piece of glass and the other in a soldier wounded by a bullet in France. In both cases recovery occurred after operation.

Cardiac and pericardial wounds may be diagnosed by the position of a foreign body as shown by X rays or its apparent course if the missile perforates the chest. This evidence may sometimes be very misleading, and as Nixon (1941, a) points out, physical signs may be equally deceptive, for a heart beating in surgical emphysema of the substernal tissues may give rise to a friction sound indistinguishable from pericarditis, or to a remarkable churning sound mistakable for hæmo-pneumo-pericardium.

It was well recognized in the last great war that if the missile had either lodged near the heart

or had passed in its immediate proximity, temporary pericardial friction sounds or loud tapping noises were sometimes heard over the cardiac area, which in most cases persisted for twenty-four hours but occasionally for several days. Such cases were reported by Rees and Hughes (1918) and by Maynard Smith (1918). These variations in physical signs associated with the movements of foreign bodies adjacent to the heart synchronous with the heart-beat, but neither in the pericardium nor heart when examined by the X-ray screen, add to the difficulties of diagnosis. Additionally, the presence of a hæmothorax will prevent clear visualization of the pericardial outline in radiographs. Sauerbruch (1941) has observed symptoms of angina pectoris with foreign bodies in the mediastinum.

Although quite a number of individual cases were reported in the 1914–18 campaign, no considerable number was published by any one surgeon or group of surgeons. Nearly all the bigger analysed groups have been recorded by surgeons in North and South America in certain parts of which continent peace-time penetrating chest wounds occur in appreciable numbers. The majority of these cases have resulted from stab wounds inflicted by knife or pick and only a small proportion by bullets.

Bigger (1939) divides cardiac injuries into four groups: (1) Patients with definite cardiac injury with but slight or moderate intrapericardial or intrapleural hæmorrhage, but without penetration into cardiac cavities—in these cases conservative measures are satisfactory as cardiac tamponade is absent. (2) Patients with definite cardiac tamponade which may be relieved by pericardial aspiration, but if pressure symptoms recur operation is indicated. (3) Patients with severe tamponade which requires immediate operation. (4) Patients with severe intrapericardial and intrapleural bleeding. Although operation is indicated it is usually followed by a fatal result.

Tamponade is due to increasing pressure on the heart by blood accumulating in the relatively inelastic pericardium, and which interferes with the filling and emptying of the cardiac chambers. It causes falling arterial pressure, rising venous pressure shown by venous distension and cyanosis in head, neck, and upper limbs, and diminution in the volume of the heart-sounds. Increasing venous back pressure on the brain may cause various symptoms referable to the central nervous system, including unconsciousness, and may suggest that the primary lesion is situated there when multiple injuries or wounds are present. It is obvious that the severity of cardiac wounds does not only depend upon the occurrence of cardiac tamponade, but that this syndrome depends upon the rate of bleeding from the heart wound compared with the rapidity of its escape from the pericardial perforation. For this reason when symptoms suggesting persistent internal hæmorrhage are present it is well to bear in mind the possibility of cardiac injury. In many cases occurring in the last war the point of penetration of the chest wall was quite distant from the heart. Radiological examination is again invaluable, but often high penetration is required to show the situation of a foreign body through the heart shadow or when hæmothorax is associated, and lateral exposures are here essential. In some cases distension of the pericardial sac with blood or air may be demonstrable. Without going into the exact technique of operation, it should be realized that the most direct approach, including where possible excision of the track of the missile, should be used; osteoplastic flaps are time-consuming and therefore to be avoided. Griswold and Maguire (1942) advise a transverse incision in civil wounds, but most explorations in war have been carried out by resections of the fifth, sixth, and the seventh costal cartilages and, if necessary, portions of the sternum. By partial suture of the pericardium and leaving unsutured the opening into the pleura caused by the missile opposite to the pericardial opening, drainage of the pericardium into the pleura, whence it can be easily aspirated, is secured. If the pericardium is sutured completely, pericardial aspiration through the xiphisterno-chondral angle will probably be required.

Infection in the pericardium when foreign bodies are retained or have perforated the sac is likely to result in a proportion of cases that have not been previously explored. In some cases, the organisms of gas gangrene may be present and cause distension of the pericardium with gas. Such infections, as often occurs in the pleura, may cause few toxic symptoms, but, as the gas and fluid increase, will cause cardiac tamponade. Such a case occurring in the last war was described by Littler Jones (1917) and rapid recovery followed pericardial drainage. Gas gangrene involving the heart muscle was also described, and the Royal College of Surgeons contained one such specimen showing multiple gas bubbles scattered throughout the heart muscle.

In draining the pericardium for infective pericarditis, care should be taken to avoid opening the intact pleura during operation and the introduction of a drainage tube into the pericardium is dangerous. The pericardium should be sutured to the skin and intermittent irrigation carried out with sterile water introduced through a small catheter.

DIAPHRAGMATIC HERNIA

Diaphragmatic hernia may develop slowly from a small perforating wound of the left diaphragm which did not appear to warrant early operation or in which the injury was not suspected at the time of wounding. In some cases a diagnosis may be made before symptoms are present by routine 'follow-up' radiological examination. Even when stomach or intestine is not shown but a hernia of omentum is demonstrable, the tendency for enlargement and the possibility of strangulation make operation

advisable at a suitable opportunity. In other cases, following crush injury and diaphragmatic laceration, hernia of the stomach and other upper abdominal contents may take place soon after injury. Unless urgent symptoms due to partial strangulation of the stomach, such as acute colicky pain, vomiting, and hæmatemesis are present, the operation should be deferred for some days or even weeks to permit recovery from the chest wall and other associated injuries.

In traumatic diaphragmatic hernia the transpleural approach is much superior to the abdominal route and temporary paresis of the diaphragm by crushing of the phrenic nerve permits easy repair and rest to the diaphragm during healing.

TREATMENT BY SULPHONAMIDES

Treatment by sulphonamides has been mentioned throughout this review and its value locally and orally, as a prophylactic and after the onset of infection, is widely recognized. Only one other point need be mentioned in regard to their use in chest injuries and that is that sulphathiazole appears to be more valuable than either sulphanilamide or sulphapyridine in the prevention and treatment of anaerobic infection which so commonly arises secondarily to collapse or hæmatoma formation in the lung and which apparently spreads downwards from the upper air-passages especially mouth and tonsils.

TRANSPORT

The rapid evacuation of chest casualties beyond the first field hospital has always been deprecated, especially after operation, and this view was emphasized by the Army Memorandum of 1917, which recommended the retention of all patients for ten days after open operation.

This view has been expressed during this war particularly by German surgeons, von Haberer (1942) and others, working on the Russian front where transport has been difficult and roads extremely bad. Unquestionably, where long, rough, and tedious journeys are entailed all seriously wounded should be theoretically retained, but the objections are obvious.

When transport from the field hospitals to the rear can be carried out under reasonably comfortable conditions, and especially when precautions such as intercostal drainage prevent the onset of conditions of tension within the pleura and the provision of reasonable warmth diminishes the incidence of pneumonia, reasons for prolonged retention in advanced hospitals are more apparent than real.

The value of air transport in the Russo-Finnish campaign has been emphasized by Linberg (1940, a, b,), who testifies to the good condition and cheerful spirit of patients transported by air compared with those transported by road.

Of 972 chest casualties received in a base chest centre, 65 per cent were transported by air, and Linberg considers it a major factor in diminishing the ultimate death-rate.

Lovelace and Hinshaw (1942) draw attention to certain risks: (1) Any injury which reduces vital capacity directly or indirectly makes air transport dangerous because of progressive anoxia, but this may be overcome by high concentration oxygen administration. (2) Patients with traumatic hæmothorax or tension pneumothorax are unsuitable for air transport because air in the pleura expands and increases pressure, even at relatively low altitudes. Quite obviously precautions can be taken against the deleterious effects in such cases.

Lovelace and Hinshaw also emphasize the dangers of expansion of the contained air in patients with diaphragmatic hernia and mediastinal emphysema. In the former expansion of the gas in the bowel may lead to strangulation or rupture.

Youlaev (1940) considers shock and pneumonia definite contra-indications to evacuation by air except under military necessity. In considering the evacuation by air of different types of wounded he cites the following factors as of importance: (1) Situation and severity of wound; (2) Distance of evacuation; (3) Altitude; (4) Risks of anoxia, abdominal distension, and air-sickness. As all other authors, Youlaev stresses the necessity for efficient oxygen supply even at low altitudes. In the Russian scheme of air evacuation a surgeon travels with the casualties, the altitude, which did not exceed 800 metres, is generally not more than 300 metres, and the plane speed is 200 miles per hour. The aerodrome at the evacuation point contains a small reception station with heated tents containing up to 40 beds. It is staffed by one surgeon, three assistant surgeons, and four orderlies. This author reports that no serious complications due to air travel were noted. More reports have been issued by the Russians on the air transport of wounded than by any other belligerent.

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SHORT NOTES OF RARE OR OBSCURE CASES

OSSIFICATION IN ABDOMINAL SCARS

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THE ossification of scars with the formation of true bone and not a mere calcification is a comparatively rare condition which presents certain curious features. In the first place, with rare exceptions, all the ossified wounds have occurred in or near the midline in the anterior abdominal wall, above the umbilicus and below the sternum. It has been suggested that there is a connexion between the formation of bone in this site and the fact that in certain reptilia bony rib-like structures occur in this region. In the human subject, at any rate, both the sternum and ribs are developed from cartilage, and as far as we are aware, in none of the described cases of ossified scars has there been any cartilage present. It is generally believed that the ossification is due to the conversion of fibroblasts into osteoblasts, and the trauma and irritation by foreign bodies or infection play a part, but no satisfactory explanation of the predilection of this site for bone formation has been put forward.

In the case about to be described, the bone was formed in membrane, and there was no sign of any cartilage.

CASE REPORT

On Jan. 17, 1942, L. L., aged 63, was taken ill with severe abdominal pain after dinner. Dr. I. P. Myers was called in, and found the patient in great pain. He had two abdominal scars, one in the left paramedian subumbilical region, the other a right paramedian scar mostly above the umbilicus. In the latter scar a hard substance was found which was painful and tender.

X rays disclosed a bony plate with irregular crenated edges in the right paramedian scar (*Fig.* 86).

The patient was admitted into a nursing home, and the bony plate was removed. It was lying in the substance of the rectus muscle between the anterior and posterior layers of its sheath, being attached to

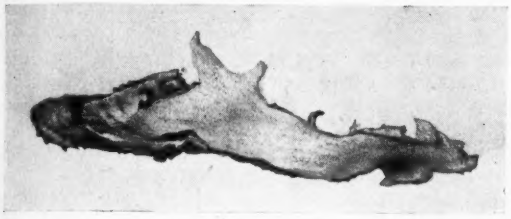

FIG. 86.—A drawing of the macerated specimen. (*Anna Zinkeisen.*)

both layers. On the deep surface of the plate and posterior wall of the sheath there were adhesions to the bowel, which were separated as far as possible, but the patient's condition was not good under the anæsthetic as he had eaten a hearty dinner a few hours before and had not had any intestinal preparation. The operation had to be completed rapidly, at the request of the anæsthetist.

The patient made good progress with regard to the wound, and was free from pain, but in spite of aperients and enemata his bowels did not open, and on the sixth day he became distended and vomited. Under spinal anæsthesia the wound was reopened and further explored, and a band of adhesions was found and divided. He then made an uninterrupted recovery.

We are indebted to Mr. Gaymer-Jones, of Windsor, for the following notes of his previous two operations: "The first operation was performed on Sept. 30, 1940, for acute intestinal obstruction. A right paramedian incision was made, and a volvulus of the pelvic colon was found. The gas was let out and the volvulus untwisted, and the loop drained through a stab incision in the left iliac region. Seven days later a stitch was removed to let out an infected hæmatoma (this may have had an important bearing on the subsequent ossification).

On April 3, 1941, the volvulus recurred, and the pelvic colon was excised through a left paramedian incision. A side-to-side anastomosis was carried out in a V manner after closing the two ends."

There is no evidence as to when the bone formed. It was not noticed at the second operation seven months after the first one, but of course this rare condition was not looked for at this operation, which was an emergency one, and the urgency and seriousness of the condition for which relief was sought would be likely to preclude any elaborate investigations.

We saw him about fifteen months after the first operation, the scar of which subsequently ossified, but there was no evidence as to how long it had been ossified. The histological evidence suggests that it had been ossified for a considerable time.

THE SPECIMEN.—We are indebted to Dr. L. R. Janes for the following description: "The specimen consists of an irregular plate of bone approximately $2\frac{3}{8}$ in. long, and varying from $\frac{1}{4}$ in. to $\frac{3}{8}$ in. in width. The average thickness is $\frac{1}{16}$ in., but at one end it is $\frac{1}{8}$ in. (*Fig.* 87).

FIG. 87.—X-ray appearances of macerated specimen, showing trabeculation.

"Microscopically (*Fig.* 88) it consists of intramembranous bone arranged in anastomosing plates

FIG. 88.—Showing the histological appearance (*see text*).

containing bone-cells. At the thicker end of the specimen the process of ossification is seen to be proceeding in the formation of an acidophil intercellular material between the collagenous fibrils, followed by the production of osteoblasts in a dense ossifying matrix. Many vessels are to be seen between these ossifying laminæ."

The necessity for economy of space in the JOURNAL prevents a discussion of the pathology. Should any reader wish to look further into this matter we have appended a bibliography.

We are indebted to Dr. Geoffrey Bourne, of the Department of Physiology of Oxford University, for the microphotograph.

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A CASE OF INTESTINAL STENOSIS FOLLOWING STRANGULATION

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WITH A PATHOLOGICAL DESCRIPTION

By ALLEN B. BRATTON, London

When inspecting bowel newly freed of a strangulating agent, it is often forgotten that between the two extremes of complete recovery and complete necrosis lies a third possibility—recovery with permanent damage and some degree of cicatricial contraction. While this is a fact so well established as to be recorded in the more comprehensive text-books of surgery, it is not frequently met with, probably because milder degrees of small-intestinal stenosis usually remain symptomless. The actual incidence may be higher than is evident.

I have met this sequel twice in a series of some 160 cases of intestinal strangulation—the first time as an autopsy finding about a year after reducing a jejunal intussusception in an elderly woman, and the second, the case I am describing, following strangulation of an inguinal hernia in an elderly man. The latter case presented two other features of interest; it was first seen as a case of auto-reduction *en masse*; and it also demonstrated that a blind end of only 14–17 cm. of small bowel may cause severe abdominal discomfort.

CASE REPORT

History.—J. B., an obese male aged 61 years, was admitted to St. James's Hospital at midday on May 30, 1941. He gave a history of having had a left-sided rupture for eight years, which he could replace himself and control moderately well with a truss. Early the same morning he replaced his rupture and applied his truss while in bed, as was his habit, but on getting off the bed he had abdominal pain, nausea, and faintness. Vomiting followed this, and the bowels acted later.

On Examination.—At midday he appeared to be suffering severe pain, and was pale and sweating. His pulse was 84 per minute, respirations 20, and temperature 98° F. His abdomen was slightly distended, generally tender on palpation, but not rigid. In the left iliac fossa was felt a deep, ill-defined and tender mass, just above the inguinal ligament. There was some hypertension and cardiac hypertrophy.

A diagnosis of reduction *en masse* was made, and he was operated on shortly afterwards under spinal anæsthesia (stovaine).

Operation.—Incision was made over the inguinal canal and the external oblique aponeurosis divided. The hernial sac was then felt impacted behind the internal oblique muscle, but it could not be brought forward, and so the muscular fibres of the internal oblique muscle were divided parallel to and above the inguinal ligament, the incision passing laterally from the normal site of the internal abdominal ring. After this the sac was readily delivered into the inguinal canal. On opening the sac odourless bloody fluid escaped, and about 12 in. of strangulated small bowel was exposed; this was freed by division of the neck of the sac. The bowel was dark and œdematous, but its sheen was good and the colour improved somewhat after a short time. The mesentery was bruised and œdematous. The constriction rings had no visible areas of gangrene, and so the bowel was judged to be damaged but viable, and was returned to the general peritoneal cavity. The sac was removed after ligation of the neck, and after repair of the incision in the internal oblique a posterior repair was performed, using catgut only, by a rectus-sheath slide.

Progress.—For some hours following the reduction the patient was pale, cold, and sweating, with a low pulse pressure, but he slowly recovered from this state. Twenty-four hours later he had an attack of vomiting which settled on restriction of his fluid intake. Seven days later he had a further vomiting attack, with generalized abdominal pain and distension. Similar attacks were repeated from time to time. He developed a wound hæmatoma, and then some superficial infection, but this settled down, and he was considered well enough to evacuate to a base hospital on July 18, 1941.

At the base hospital these attacks of abdominal pain with nausea or vomiting continued, and so a laparotomy was performed on Aug. 7, 1941, through a right-sided paramedian incision. Small bowel lying in the left iliac fossa and adherent there, was found to be obstructed and was short-circuited by a lateral anastomosis after freeing the adhesion, which did not appear to be the whole cause of the obstruction (extract of notes from Base hospital). Following this the patient had complete relief for several weeks and returned home on Oct. 21, but then attacks of abdominal colicky pain referred vaguely to the subumbilical region, and worse half an hour after meals, recurred. With the pains he had nausea, but no vomiting, and his bowels acted freely, even with a tendency to looseness. He was re-admitted to St. James's Hospital on account of these symptoms. He looked well and remained apyrexial. The hernia and laparotomy scars were sound, there was no abdominal distension, guarding, or tenderness, and no mass was felt. A radiograph after a barium meal disclosed no abnormality in the passage of barium through the bowel. With rest the pains became less severe and the patient was discharged on Dec. 4. His constant complaint of the pain as an out-patient decided me to readmit him for abdominal exploration.

Operation was performed on Dec. 30 under general anæsthesia. A left paramedian incision was made. The hernial site was firm and free of adhesions. The only abnormality present was in the middle segment of the small bowel, where a small loop was found which had been short-circuited by a wide antiperistaltic lateral anastomosis. About the middle of the short-circuited loop was a thickened and stenosed area (*Fig.* 89). Proximal to this stenosis and distal to the anastomosis the bowel was dilated, hypertrophied, and œdematous. Distal to the stenosed area as far as the anastomosis the bowel was narrow and empty. Apart from this loop the bowel appeared normal, with an excellent passage through

the anastomosis. It was considered that the pain was due to excessive peristalsis in the distended bowel proximal to the stenosis, and so the loop of bowel was resected, leaving the anastomosis undisturbed.

The patient made a good recovery from this operation, and has had no further abdominal pains (Sept., 1942).

THE SPECIMEN (Dr. A. B. Bratton).—The specimen is a portion of small intestine (20 cm. long) which has

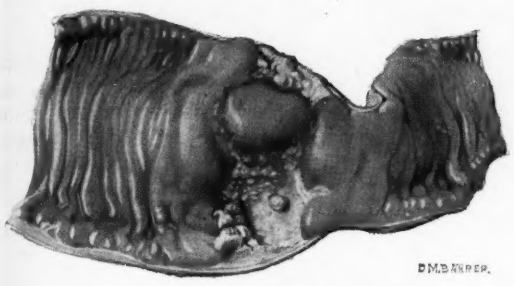

FIG. 89.—Drawing of the stenosed area of the small gut.

been opened along the antimesenteric border, laid out flat, and fixed in formalin. At one end it is 8 cm. in circumference; 11 cm. from this end it narrows sharply down to 3·5 cm. circumference and then widens equally sharply, the stenosed part being 3 cm. long; the remaining 7 cm. is 5 cm. in circumference. The wider end may be considered and will be referred to as the proximal end, the narrower as the distal. A portion of the mesentery (up to 3 cm. wide) is attached; this appears to be slightly thickened, especially in the region of the stenosis.

The peritoneal surface shows widespread irregular fine white or greyish-white fibrous thickening with a few small fibrous tags. The wall at each end is 0·7 cm. thick, including valvulæ conniventes, which are well defined over the greater part of the mucosal surface. In the stenosed portion and proximal to it, for a total length of 8 cm., the mucosa is raised, uniform, and flat, showing no valvulæ conniventes; its surface is faintly granular and yellowish-white; the thickness of the wall is here up to 1·2 cm. and the coats of the wall are indistinct on section. Proximal to the stenosis there is an ulcer, varying from 3 cm. to 4 cm. in width, which surrounds the lumen except for a band (3 cm. wide), one border of which coincides with the mesenteric attachment; the floor of the ulcer is rough and ragged, except for a few small islands (up to 0·5 cm. diameter) of raised mucosa. There is a linear transverse furrow joining the distal extremities of the ulcer.

For microscopical examination the full length of the raised area of mucosa was taken in three longitudinal blocks and one was taken from the ulcerated area. These were stained with hæmatoxylin and eosin, Weigert's iron hæmatoxylin and Van Gieson, and Weigert's fuchselin for elastic.

Throughout the raised area fibrosis is present in all coats, especially in the serosa and submucosa. In the muscularis there are only fine scattered strands, except at and just distal to the site of stenosis, where there is considerable destruction of both coats, especially the outer; proximal to this point the inner coat is at least twice the thickness of the outer, distal to it the outer is the thicker. There are numerous dilated venules and lymphatics in the serosa, in which coat they are most numerous at the stenosis but more widely dilated proximal to it, and in the submucosa, where the lumen of one vein is obliterated by old completely organized thrombus; there are numerous dilated lymphatics in areas of fibrosis in the mucosa just proximal to the stenosis. The glandular crypts and villi of the mucosa are considerably distorted by fibrosis, and in many places the epithelial cells appear larger and less numerous than normal; the muscularis mucosæ is irregularly thickened and interrupted by fibrous strands; the surface of the mucosa is almost flat and no valvulæ conniventes are present. There is considerable infiltration of all coats with plasma cells, mononuclears, and eosinophil and some neutrophil leucocytes; the infiltration is diffuse except in the serosa, where it is focal. The linear transverse furrow joining the distal margins of the ulcer is seen to be a narrow ulcer extending down to the inner muscular coat.

In the ulcerated area the ulceration has destroyed the greater part of the mucosa and submucosa; a few irregular mucosal tubules are still present. The other coats in general resemble those in the proximal part of the area described above.

The appearances suggest that the present condition is the result of the previous strangulation, the fibrosis of the muscularis at the site of stenosis being the point of maximum constriction of, and severest damage to, the wall of the bowel. The dilatation of venules and lymphatics is a residue of the vascular occlusion, there being evidence of old venous thrombosis again at the site of stenosis. The mucosa must have been extensively damaged and had probably sloughed away in the raised and ulcerated areas, that now present in the former having regenerated: the fibrosis and irregularity of the muscularis mucosæ and of the crypts and villi are evidence of this, bearing a strong resemblance to the appearances in regeneration of mucosa in the healing of a gastric ulcer. In the floor of the ulcerated area similar regeneration has only taken place in a few small areas.

COMMENTARY

In the text-book descriptions of this condition it is suggested that the stenosis occurs at the part of the bowel actually compressed by the constriction ring, and may be double. C. C. Choyce (*A System of Surgery*, 1932) states that the stenosis may be 1 in. or more in length.

In this case the total extent of severe damage is 8 cm., though the most stenosed part is only 3 cm. long. Much of this damaged area must include bowel which lay between the constriction rings and probably also the distal constriction ring. It seems that not only the area made anæmic by compression at the neck of the sac but also the strangulated bowel lying in the sac may suffer permanent damage. The dilatation of venules and lymphatics is confirmatory evidence of this. While it is understandable that damage to the serosa and muscle coats may result from prolonged slowing or even cessation of the bloodstream through them, it is still more easy to comprehend that the mucosa would suffer even more severely, being in contact with the stagnant and probably infected intestinal content, resulting in a degree of ulceration that might be too severe to heal. The tendency to heal in the area proximal

to the severest stenosis would be hampered in this case by the distension of the bowel, giving a greater area to be covered with new mucosa. The attempt at mucosal regeneration suggests that in the absence of an actual obstruction moderate degrees of mucosal gangrene may be repaired. The age and degree of vascular degeneration would no doubt have some effect in determining the amount of thrombosis and of gangrene.

It is instructive to notice the marked and persistent discomfort complained of by the patient—a phlegmatic individual—apparently originating in the presence of a 'blind end' of about 14 cm. of small bowel, which lay beyond a very wide lateral anastomosis. No general deterioration of health such as has been recorded in the presence of much longer blind ends was noticed.

The auto-reduction *en masse* presented no features markedly different from other such cases on record. Although approach by a paramedian incision is often described for this complication, I have used an inguinal incision in three personal cases of reduction *en masse*, and, combined with division of the fibres of the internal oblique muscle near their origin, have found excellent access.

I am indebted to Dr. W. Allen Daley, Medical Officer of Health, London County Council, and Dr. Norman S. Craig, Medical Superintendent of St. James's Hospital, for permission to publish this article.

ENTEROGENOUS CYST OF THE DUODENUM

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ACCORDING to Evans (1929), developmental enterogenous cysts are not remarkably uncommon. Nevertheless, only 9 cases of such cysts arising in the duodenum have been described. An example of the latter condition, occurring in an infant of seven weeks and treated by gastro-duodenal resection with recovery, may be thought of sufficient interest to record.

CASE REPORT

HISTORY and PRE-OPERATIVE FINDINGS.—The child, a female, the only child of normal parents, was born on Oct. 27, 1941; the birth weight was 7 lb. 13 oz. On Nov. 17 she was admitted to the Karitane Hospital for Babies, with a history of frequent projectile vomiting. The weight was then 6 lb. 8 oz. She was too feeble to suckle, and was fed on expressed breast milk. Projectile vomiting continued in large quantities, and occurred once or twice daily. On Nov. 26, the child was transferred to the Wellington Hospital. At this stage she weighed 6 lb. 13 oz., and was frail, with poor skin elasticity. The abdomen was large, and in the right half there was a palpable, smooth, cystic tumour, which was slightly mobile. The bowel motions were normal, the urine normal, and the blood examination showed nothing of significance.

A diagnosis of renal neoplasm was first considered. An excretion pyelogram (*Fig.* 90), however, showed a normal-looking right kidney, with the tumour shadow superimposed, while the gut was pushed to the left, obscuring the left renal shadow. The possibility of a mesenteric cyst causing pyloric obstruction was also considered. A barium meal was not done, owing to the likelihood of the feeding being upset thereby.

With small frequent feedings and subcutaneous injections of saline, the weight reached 7 lb. 9 oz. and remained stationary for several days. Severe vomiting commenced again, and it was accordingly decided that operation should be proceeded with before the child lost ground.

OPERATION.—Operation was performed on Dec. 12 and was carried out entirely under local anæsthesia.

The abdomen was opened by a transverse incision on the right side, extending from the tip of the twelfth rib to the lateral margin of the rectus abdominis muscle. A cyst 3 in. in diameter was found lying behind the transverse colon; it was intimately attached to the inferior surface of the pyloric part of

FIG. 90.—An excretion pyelogram showing a functioning right kidney, with the tumour shadow superimposed, while the gut is pushed to the left, obscuring the left renal shadow.

the stomach and the first part of the duodenum, which were stretched like a band across the cyst (*Fig.* 91). An attempt was made to dissect the duodenum off the cyst, but this was soon found to be

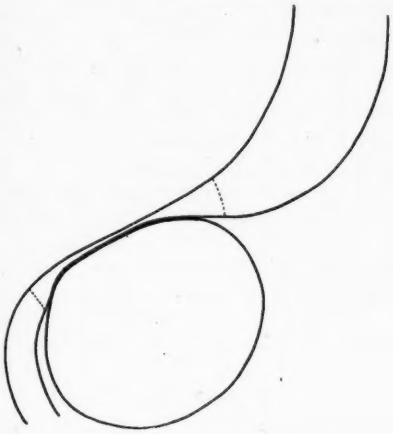

FIG. 91.—A drawing showing the condition found at operation. The dotted lines indicate the points of section.

impossible. The involved portion of the stomach and duodenum, bearing the cyst, was therefore resected and an end-to-end anastomosis made.

SUBSEQUENT PROGRESS.—Following the operation a blood transfusion of 100 c.c. was given, and immediate feeding was commenced, as after Rammstedt's operation for pyloric stenosis. Fluid was also given as subcutaneous saline for the first three days.

Recovery was entirely uneventful, except for the occurrence of a stitch abscess. The child was discharged from hospital sixteen days after operation; she then weighed 7 lb. 1 oz. She was weaned on March 15, 1942. At the age of six months she weighed 14 lb. 2 oz. and was normal in all respects.

connexion between the lumen of the bowel and the interior of the cyst can be found.

"Microscopically, in the cyst wall are all the components of the bowel. There is a well-formed

FIG. 92.—A photograph of the cyst with the flattened duodenum running over it. The superior wall of the duodenum has been partly cut away, to show the small ulcer in the inferior wall in contact with the cyst.

muscular coat, which has circular and longitudinal fibres. In addition, there is a well-defined mucous glandular inner lining to the cyst; this is atrophied and flattened, but numerous glands, which have the appearance of the duodenal glands of Brunner, can be made out.

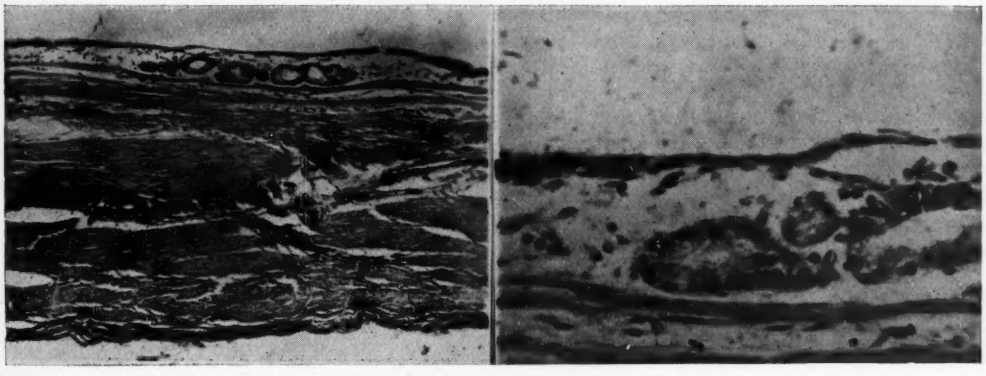

FIG. 93.—Microphotograph of the cyst wall, showing columnar epithelium, glands in the submucosa, and the smooth muscle wall.

PATHOLOGICAL REPORT.—Dr. J. O. Mercer, Pathologist to the Wellington Hospital, reports as follows: "The specimen consists of a unilocular cyst containing clear fluid. The wall of the excised bowel runs over the cyst, and the wall of the bowel is flattened and thinned. The muscular coat of the bowel is closely incorporated in the cyst wall and cannot be separated from it by blunt dissection. The mucosa of the bowel is atrophied, and at one point presents a small circular superficial erosion. No

"This is a developmental cyst of the duodenum, and has developed as a diverticulum from the first part of the duodenum."

The naked-eye appearance of the cyst is shown in *Fig.* 92, and the microscopical appearance in *Fig.* 93.

REVIEW OF THE LITERATURE

Nine cases of enterogenous cyst of the duodenum have been described, with 3 recoveries;

of the 9 cases 5 occurred in females, 1 in a male, while in the remaining 3 information as to the sex of the patient is not available.

Gardiner and Hart (1935) report the case of a girl of 15 years, with a 22 months' history of intermittent abdominal pain and vomiting. Hæmatemesis and melæna occurred at 6 months and at 2 years of age. She presented a fullness and a mass in the region of the gall-bladder, thought to be a choledochus cyst. At operation a large cyst was found bulging into the first and second parts of the duodenum, which were flattened over it. The cyst was considered irremovable, as it was probably associated with the bile and pancreatic ducts. The cyst was anastomosed to the duodenum by working from within the duodenum. Recovery was uneventful.

Sanger and Klopp (1880) (quoted by Gardiner and Hart) report the case of a newborn child who died after a difficult delivery. The viscera were transposed. The abdomen contained five cysts, one from an accessory liver, one from an accessory bile-duct, and three from the intestine. One of these three originated in the duodenum; it was the size of a walnut, and was composed of the normal layers of the duodenal wall.

Roth (1881) (quoted by Gardiner and Hart) reports the case of a newborn male infant dying after birth. The abdomen was distended and contained a large, pedunculated, thin-walled cyst arising in the duodenum but not communicating with it. The cyst contained all the layers of the normal intestine. There was also an enterogenous cyst of the mediastinal œsophagus.

Meyer (1919) (quoted by Gardiner and Hart) reports the case of a female infant of three weeks who began at thirteen days to vomit after each feed, and was emaciated at three weeks. She was not operated on. At autopsy the pylorus and the first part of the duodenum were found dilated, and in the medial wall of the duodenum was a cyst the size of a hen's egg, and extending from the pylorus to the ampulla of Vater. There was no communication with the duodenum. The cyst contained the normal layers of the duodenum and occupied a submucous position.

Waugh (1923) reports the case of a 19-days-old female in whom were noted regurgitation of milk and constipation. On examination there was a firm mass in the right abdomen, extending from the costal margin to the ilium. At operation a mass presented on the outer side of the ascending colon. The cyst was shelled out as far as the midline, where it was found adherent to the posterior wall of the duodenum. The first part of the duodenum seemed to run into the upper part of the cyst, and the third part from the lower portion. The intervening portion of the duodenum was stretched like a ribbon across the cyst, and Waugh noted that it was impossible to think of dissecting them apart. The cyst was semi-transparent. The cyst was packed with gauze but recurred in a few weeks. The child died of pneumonia before further surgery was possible. The microscopical slide showed longitudinal and circular muscle, but the mucosa is not mentioned.

Maddox (1918) reports a case of cyst of the duodenum simulating pyloric stenosis. The sex is not mentioned. The child commenced to vomit at the age of six weeks; vomiting occurred once daily, and was sometimes projectile in character. At operation, at three months of age, a cyst was found adherent to the duodenum in the region of the ampulla of Vater; the pancreatic duct appeared to end in the wall of the cyst. The child died following posterior gastro-enterostomy. The cyst wall contained columnar cells and muscle.

Smith (1930) published a case of enterocystoma of the duodenum simulating congenital pyloric stenosis. A female of two weeks commenced to vomit after every feed, and the vomiting was sometimes projectile. After a feeding trial of two weeks the abdomen was opened, disclosing a cyst of the anterior wall of the first part of the duodenum. The stomach was opened and dilators were passed easily along the duodenum; the cyst was drained. The child died. At post-mortem the cyst was found considerably reduced in size.

Basman (1938) described an enterogenous cyst of the duodenum simulating pyloric stenosis. A four-weeks-old girl presented with vomiting and loss of weight for two and a half weeks. At laparotomy a cyst of the duodenum was aspirated. This procedure relieved the symptoms for seven days, when the abdomen was again opened and the cyst again aspirated as it could not be enucleated; a gastro-enterostomy was performed and this was followed by immediate feeding. The child recovered, and at six months weighed 17 lb. 8 oz.

A case with recovery has also been described by Gillespie and Rogers (1940), but no particulars can be quoted since the journal is not available here.

AETIOLOGY

Evans suggests that enterogenous cysts of the alimentary canal originate as diverticula from the gut, the communication between the diverticulum and the intestine then becoming obliterated. The cyst thus formed may lie beneath the mucosa, between the muscle layers of the intestinal wall, beneath the serosa, or it may occur as a mesenteric cyst between the layers and the mesentery.

It appears to be an established fact that, during the development of the embryo, a curious overgrowth lining occurs throughout the duodenum in the fifth and sixth weeks, to such an extent that the lumen is largely blocked by it. Later, according to Lewis and Thyng (1908) and Keibel and Mall, there make their appearance, in the proliferated epithelium, numerous vacuoles or pits, which give rise to local bulging in the wall of the duodenum, and which normally become confluent and thus re-establish the lumen. Lewis and Thyng suggested that duodenal diverticula might

be developed from such vacuoles or pits, but this theory has not met with any general acceptance as an explanation of the occurrence of duodenal diverticula in general. Whether the persistence of such a vacuole represents the starting point of a congenital diverticulum which, according to the theory of Evans, gives rise to an enterogenous cyst, must apparently remain undetermined.

DIAGNOSIS

In a case presenting partial duodenal obstruction, with the presence of a large abdominal tumour, the possibility of an enterogenous cyst should be considered. The tumour is quite unlike the small, hard tumour met with in a case of hypertrophic pyloric stenosis.

In contrast with congenital duodenal atresia, the vomiting occurs later and is less severe.

TREATMENT

As the obstruction appears always to be partial, every effort should, in the first instance, be made to improve the patient's condition by small frequent feedings. Dehydration should be corrected by the administration of fluid either subcutaneously or intravenously, according to the age of the patient. In infants, when operation is decided upon, local anæsthesia is considered of great importance in contributing to a successful issue, the more especially as the operation may be a prolonged one.

Successful results have been obtained from the following procedures: (1) Drainage of the cyst into the duodenum; (2) Aspiration of the cyst followed by gastro-enterostomy; and (3) Resection with anastomosis. Resection with anastomosis is probably the ideal, but it is not likely to be regarded as feasible, at any rate as a primary procedure, in cases where the bile and pancreatic ducts are involved. It is suggested that simple prolonged drainage of the cyst might relieve the obstruction until such time as the patient is fit for radical surgery, if necessary.

In infants it is considered important that feeding should be commenced immediately after operation, as is usual after Rammstedt's operation.

SUMMARY

1. A case of enterogenous cyst of the duodenum, causing obstruction and treated by resection, with recovery, is described.
2. The available literature is reviewed.
3. The aetiology is considered.
4. Suggestions for treatment are made.

My thanks are due to Dr. J. O. Mercer for the pathological report and the photographs; and to Dr. John Cairney, Medical Superintendent, Wellington Hospital, for help in publishing this case.

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ABDOMINAL INJURIES LEADING TO GASTRIC ULCERATION AND HÆMATEMESIS IN A BOY OF 15

BY J. B. KINMONTH
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GASTRIC ulceration due to trauma is unusual and well-substantiated cases are rare in the literature, although several papers have been written on this subject since Potain first reported a case in 1856.

In the case described below, evidence of the traumatic aetiology is better than in most, and several interesting features are present.

CASE REPORT

A boy of 15 was admitted to the Ingham Infirmary, South Shields, on Dec. 1, 1941, after being crushed between two wagons half an hour before admission.

He was in a moderately shocked condition. There was bruising of the abdominal wall, with tenderness and slight rigidity in the left hypochondrium. There were no extra-abdominal injuries and a catheter withdrew normal urine.

He was observed for an hour, during which time his condition deteriorated, despite general anti-shock measures. He vomited a little 'coffee-grounds' fluid and the rigidity increased.

FIRST OPERATION.—It was considered that he had an injury to his stomach and intraperitoneal bleeding, possibly due to a ruptured spleen. One litre of blood was given rapidly, anæsthesia induced with gas, oxygen, and ether, and the upper abdomen opened through a midline incision.

Exploration revealed, firstly, laceration of the anterior wall of the stomach, some 3 in. long, involving the seromuscular layers only; secondly, the left side of his abdomen contained more than half a pint of blood, in the left infracolic compartment and paracolic

gutter. This was found to come from a complete tear in the mesentery of the small intestine, parallel to the long axis of the bowel and involving jejunal branches of the superior mesenteric vessels. From a point 1½ in. distal from the duodeno-jejunal flexure, some 10 in. of jejunum was dark blue and non-viable. The bleeding vessels were ligated and the devascularized length of jejunum was resected and an end-to-end anastomosis performed. This was difficult because the length of jejunum proximal to the devitalized area was short and had sustained superficial lacerations which required repair.

Attention was then turned to the stomach and the laceration inverted with a single continuous Lembert stitch of catgut.

Lastly, there was found a laceration of the pancreatic head above the superior mesenteric artery, ½ in. long, exuding milky fluid. This was repaired with a few catgut stitches. The abdomen was closed without drainage.

PROGRESS.—Convalescence was satisfactory until Dec. 12, when two large hæmatemeses occurred. In the following days large melæna stools were passed and the patient became progressively more anæmic. Œdema of the face and legs and blisters of the legs appeared—presumably due to the blood loss. Four litres of blood were given during this time.

On Dec. 18 further hæmatemesis occurred. It was considered that unless hæmostasis could be secured by surgical means, death was inevitable.

SECOND OPERATION.—Operation was performed under local anæsthesia, including cœliac-plexus block. There were numerous adhesions. A small perforation was accidentally made in the transverse colon where it was adherent to the previous incisional scar: it was closed with a purse-string suture. Adhesions present between the liver and the stomach (at the site of the previous injury and repair) were separated. No trace of catgut could be seen at the site of the injury. A vertical incision parallel to and to the right of the scar was made in the stomach so that through it inspection might be made of the mucosa at the site of the original laceration. An ulcer somewhat larger than a sixpence was found in the centre of the site of injury, and several small vessels in its floor were bleeding. A strip of stomach bearing the ulcer and scar tissue was excised and the opening in the stomach closed with two layers of sutures.

During and immediately following operation three further litres of blood were given.

PROGRESS.—No further abdominal complications occurred. Meulengracht diet and dosage with ferrous lactate were commenced after operation.

On Dec. 24 the hæmoglobin was 58 per cent. Gangrene of the medial four toes of each foot became manifest soon after operation, presumably due to the extreme exsanguination, and required amputation when the patient's condition permitted it (Jan. 28, 1942, under general anæsthesia).

He was discharged from hospital on March 7, 1942, with all his wounds healed.

Dr. H. A. Cookson reported that the microscopical appearances of the excised piece of stomach were those of a typical peptic ulcer.

DISCUSSION

Gerendsay (1933) suggested that the following points should be substantiated in order to establish the traumatic origin of a gastric ulcer:—

1. That no ulcer existed previous to injury.
2. The injury should be of a nature likely to traumatize the stomach.
3. The resultant ulcer should be demonstrated by convincing physical signs, or at operation or autopsy.

In the case under discussion, points (2) and (3) are established. The first point is the most difficult to prove. In this case the evidence is better than most. There was no previous history suggesting stomach trouble, ulceration is very rare at the age of 15, and it would seem an extraordinary coincidence if the laceration observed lay immediately over a pre-existing ulcer (of which anyway there was certainly no palpable or visible evidence at the first laparotomy).

Normal gastric mucosa heals remarkably well, and small lacerations are known to heal rapidly without forming an ulcer.

The mechanism in this case was probably similar to that suggested by Eusterman and Mayo (1934): "... If hæmorrhage is delayed it is reasonable to presume that the trauma produced a submucosal hæmorrhage, resulting in a hæmatoma of variable depth and size followed by necrosis, proteolysis, and eventually crateriform ulceration."

It may have been aided by delay in stomach emptying (due to the nearby anastomosis at the duodeno-jejunal flexure) since this is known to favour ulcer formation (Hughson, 1927).

Whatever may have been the pathological minutiæ of the formation of this ulcer, the macroscopic evidence of its traumatic origin would appear to be as well-substantiated as any of the few recorded comparable cases owing to the opportune and interesting train of clinical events.

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CONGENITAL RETARDATION IN DEVELOPMENT OF THE CARPAL NAVICULAR, FIRST METACARPAL, AND STYLOID PROCESS OF THE RADIUS

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THE rarity of this condition alone warrants its description. I can find no previous account in the English literature. It also serves to emphasize the enormous importance of the thumb when power of grip comes under consideration. It is from the loss of grip and liability to strains that the condition may be diagnosed.

The case described by M. Botreau-Roussel (1922) has a bilateral complete abscence of carpal navicular and on the left hand abscence of the proximal half of the first metacarpal.

CASE REPORT

The patient was a female aged 29 years. She was sent up to the Fracture Clinic complaining of pain in the left wrist following a sprain the previous week.

HISTORY.—She had always suffered from weak wrists, the left being weaker than the right. She found that while doing her ordinary housework she frequently sprained her left wrist. The injuries causing these sprains were trifling and not likely to have any effect on a normal person. The sprain a week previously was caused by lifting a kettle full of water.

ON EXAMINATION.—The left thumb, hand, wrist, and distal part of the forearm showed an atrophy on the left side, especially marked in the thenar muscles. The thumb lay adducted alongside the index finger and full abduction of the thumb was about 20° from the long axis of the ulna (*Fig.* 94).

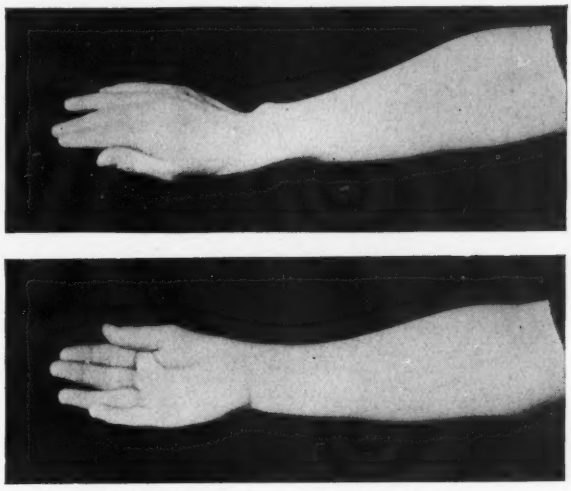

FIG. 94.—Photographs showing the deformity (*see* text).

X-ray Examination (*Fig.* 95).—There were three changes to be seen in the radiograph :—

1. *Navicular*: This consisted of a tiny rudimentary navicular, shaped like a stubby tadpole. It measured ½ cm. by ¼ cm. The distal end or head of the tadpole had a fairly round, clear-cut edge, the proximal end or tail an indistinct fluffy margin.

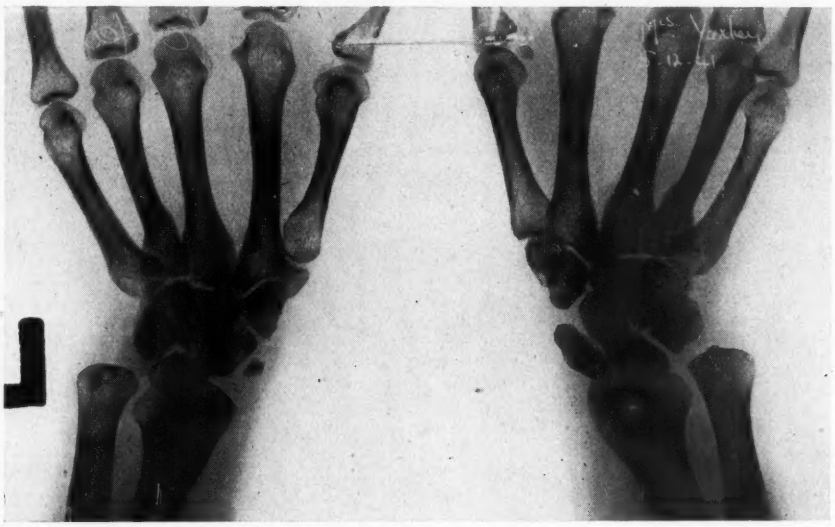

FIG. 95.—Radiographs showing changes in left hand compared with right. (For description, *see text.*)

The scaphoid could not be felt on palpation of the anatomical snuff-box with the hand in full ulnar deviation. Power of grip of the hand was one-eighth of normal.

2. *Radius*: The distal end of the radius showed a complete absence of the radial styloid and some shortening when compared with the ulna at the radio-ulnar joint.

3. *First metacarpal*: The proximal end had no tubercle for the insertion of the abductor pollicis longus, and resembled the head of a metacarpal.

In the right hand these deformities were present, but not so well marked.

DISCUSSION

I have been unable to trace the description of any such case in the English literature. Two cases of absence of the carpal navicular have been described in the Continental literature during the last 30 years.

The most marked feature has been the loss of grip. The other fingers were normal in development, but owing to the weak thumb the grip was reduced to an eighth of normal. The sprains have been caused by the patient performing everyday tasks which were, however, too heavy for her weakened wrist.

I have been unable to trace any family history in this case.

REFERENCE

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ATRESIA OF THE SMALL INTESTINE

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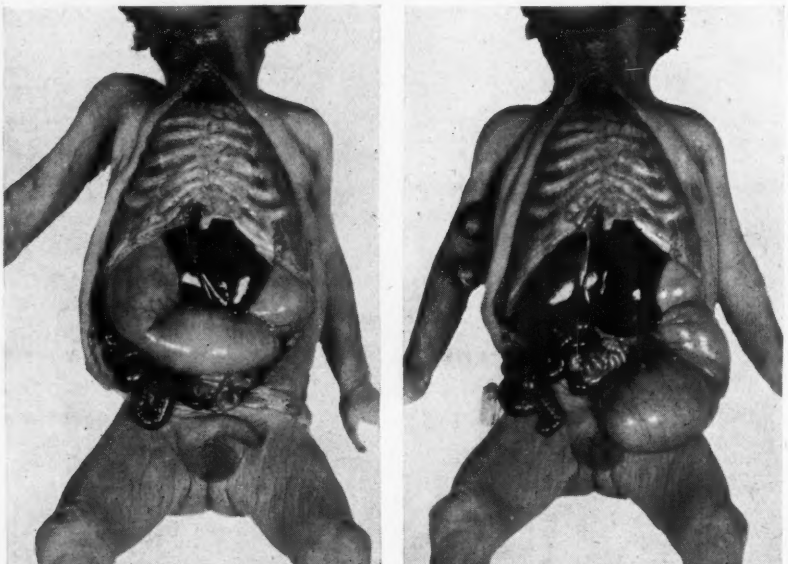
WHILE conditions of atresia of the small intestine are well recognized, and numerous cases have been collected (*see* Symposium, *Ann. Surg.*, 1942, **116**, 321), the condition is sufficiently rare to warrant the report of fresh cases.



A B

FIG. 96.—A, Position of the viscera on opening the abdomen, showing the greatly distended stomach and duodenum. B, The distended portions of bowel are pulled outwards and to the left; the distal blind end of jejunum is seen lying in the right inguinal region.

CASE REPORT

A three-day-old child, I. J., was admitted to the African Hospital, Lagos, on Jan. 19, 1942, with a history that it vomited everything taken by mouth, had been completely constipated since birth, and did not cry well. The child weighed 4 lb. 8 oz. and was very emaciated and undersized. The abdomen was distended and there was a small right inguinal hernia which could be reduced with difficulty. No tumour could be felt in the abdomen. The condition was obviously one of intestinal obstruction, but the condition of the child was so bad that operative treatment could not be considered.

The child died on Jan. 21, and a post-mortem examination was performed. The condition found is illustrated in the accompanying photographs. The small intestine ended blindly 3 in. beyond the

duodeno-jejunal flexure. The stomach, duodenum, and the first 3 in. of the jejunum were enormously distended, filling more than half of the abdominal cavity (*Fig.* 96). The remainder of the small intestine and the colon were empty. About one-third of the way along the small intestine there were three small isolated portions of bowel, blind at each end, and attached to the main mesentery by small mesenteric folds; the blood-supply to these was intact. There was no trace of bands connecting these portions of gut with the main length of small intestine, and there did not appear to be any dimpling of the bowel to suggest that these isolated lengths were diverticula which had become cut off. There was no band connecting the two blind ends of the jejunum. (*Fig.* 97.)

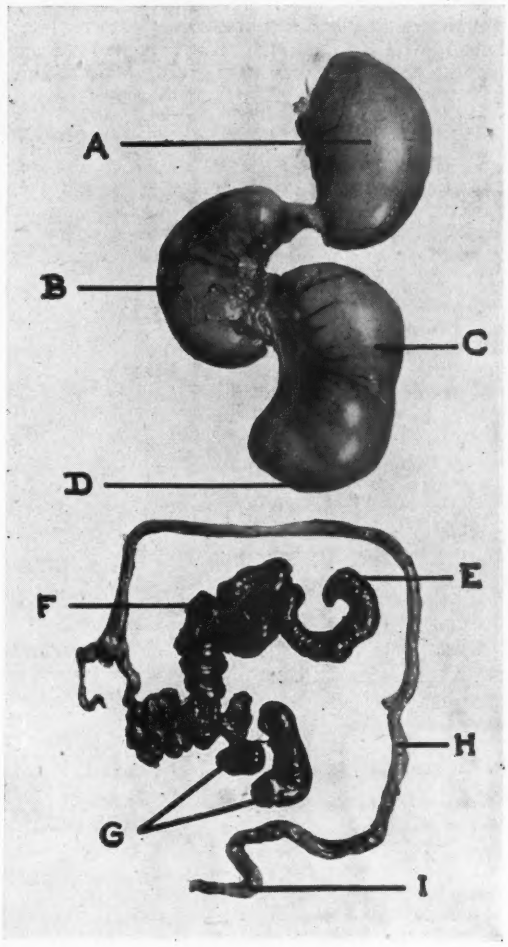


FIG. 97.—Photograph of the gastro-intestinal tract when dissected out. A, Stomach; B, Duodenum; C, First 3 in. of jejunum; D, Proximal blind end of jejunum; E, Distal blind end of jejunum; F, Coils of jejunum; G, Three small isolated portions of small intestine; H Colon; I, Rectum.

DISCUSSION

This case differs from those already described in that there was no fibrous band linking the two blind ends of jejunum, and there were three isolated segments of small intestine. The abnormality appears to have been confined to the developmental mid-gut, and not to have extended throughout the whole of it. Neither could the abnormality be said to have occurred at the junction of the fore-gut and mid-gut as the terminal duodenum and first part of the jejunum were entirely normal.

We wish to thank the Hon. the Director of Medical Services, Nigeria, for permission to publish this case report, and Mr. J. E. Knight, Laboratory Superintendent, for the photographs.

TORSION OF THE SPLEEN SIMULATING CARCINOMA OF THE COLON

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SINCE Abel's paper in 1933 on wandering spleen with torsion of the pedicle, Bohrer has cited another 20 cases from the literature. The preoperative diagnosis in the majority of cases was that of twisted ovarian cyst, but in one case carcinoma of the colon was suggested. In spite of the comparatively long duration of symptoms before operation, 19 cases made a good recovery. Abdominal pain and vomiting appear to have been common and marked features, but a tumour was not always palpable. The difficulty of arriving at a correct diagnosis is even more clearly indicated in the clinical details of the following case.

CASE REPORT

In October, 1941, a woman of 74 was admitted to hospital with a diagnosis of intestinal obstruction. She had for three days complained of pain in the left iliac fossa, and had vomited frequently. Her bowels had not been opened for four days, but up till this time she had been well and had not noticed any irregularity of the bowels nor any blood in the motions.

ON EXAMINATION.—This showed a woman fairly fit in appearance and looking younger than her years. Temperature, pulse, and respiration were normal. The abdomen was slightly distended, more marked in the left lower quadrant. Palpation revealed a hard but ill-defined tender mass well out in the left iliac fossa. It appeared to be rather smooth for a carcinoma of the colon and of unusual size for so short a history. Pelvic examination revealed nothing abnormal.

A diagnosis of carcinoma of the sigmoid colon, probably causing obstruction, was made, as several enemas failed to produce a satisfactory result, and no wind was passed. The patient was vomiting small quantities from time to time.

Sigmoidoscopy was entirely negative, except for an empty bowel, while a barium enema passed along the colon and well beyond the lump after considerable delay here, with much distortion of the colon. The following day the lump was much more prominent and more tender, although the general condition of the patient appeared unchanged. Operation was decided upon.

AT OPERATION.—Under gas and oxygen and ether the abdomen was explored through a left paramedian incision. Considerable difficulty was found in identifying the abdominal mass, as it was surrounded by distended coils of small intestine which were adherent to the surface. After gently separating the bowel with the fingers, a large, smooth tumour was delivered, which proved to be a wandering spleen, whose pedicle had twisted at least six times. Its surfaces showed large areas of necrosis covered by lymph. It was very easily removed and the abdomen was closed without drainage.

The patient made an uninterrupted recovery, and recently reported that she was in good health.

Comment.—The interest in this case lies in the rarity of the condition of wandering twisted spleen, and also in the fact that clinically it so closely resembled a case of intestinal obstruction. Torsion of intraperitoneal organs or tumours frequently present problems of diagnosis because of the degree of vomiting and obstinate constipation. The vomiting is no doubt due to peritoneal irritation from the presence of a necrotic tumour, and also possibly absorption of products of tissue breakdown. The constipation probably results from a local ileus of the coils of intestine in contact with the twisted tumour.

A CASE OF SPONTANEOUS RUPTURE OF A TUBERCULOUS BLADDER

BY JAMES MORONEY

DEPUTY MEDICAL SUPERINTENDENT, BROADGREEN HOSPITAL, LIVERPOOL

OF all acute abdominal emergencies, spontaneous rupture of a tuberculous bladder must be amongst the rarest.

CASE REPORT

HISTORY.—A female factory worker, aged 22, was admitted to hospital complaining of lower abdominal pain and anuria of 28 hours' duration. The previous day, a Sunday, she had stayed in bed as she had felt tired. She had had frequency of micturition for two years. Her father had died from phthisis.

ON EXAMINATION.—There was generalized tenderness over the lower abdomen, which was resonant. No urine was recovered from the bladder by catheterization. The temperature was 101°, the pulse 106.

OPERATION.—A lower paramedian incision was made. The peritoneal cavity contained clear urine, and on the posterior wall of the bladder was a perforation, the size of a pea, from which urine was exuding. The surrounding 1 in. in diameter was a thin grey sloughy area covered with five greenish-yellow tubercles on the peritoneal surface. The urine was mopped up, and with difficulty on account of the friability of the bladder wall the peritoneal surfaces were inverted to close the rent. The pelvis was drained and an extraperitoneal suprapubic fistula was established, a self-retaining catheter being inserted. This was chosen in preference to an indwelling urethral catheter, as it was felt that should any blockage occur recurrence was inevitable on account of the muscular destruction.

POST-OPERATIVE HISTORY.—There was some initial improvement, but death occurred a week later. Tubercle bacilli were recovered from the urine.

POST-MORTEM EXAMINATION (Dr. D. Prysor Jones).—The bladder was effectively sealed off from the peritoneum. Peritonitis absent. The right kidney was destroyed by the tuberculosis, and the left, which was hypertrophied, contained a large tuberculous focus. Both ureters were thickened. The bladder was caseous.

Microscopical Pathology (Dr. R. T. Chadwick).—All tissues examined showed very extensive evidence of tuberculosis. Rupture of the bladder wall can easily be understood in view of its caseous condition.

DISCUSSION

Extensive caseation with little attempt at fibrosis was the dominant feature of the pathology. Slight overdistension while lying in bed was probably the immediate cause of rupture.

It would appear that should death from peritonitis be averted, the chances of survival are none the less very poor, since rupture is likely to be associated only with the most acute and extensive tuberculous destruction of the urinary tract.

Including spontaneous fistulæ connected with a tuberculous bladder, I can trace only 17 cases clinically and 14 cases at post-mortem (Wyatt and Douglass, 1938).

No case of intraperitoneal rupture has been reported to have survived.

I have to thank Dr. L. Findlay for his help with this case.

REFERENCE

WYATT, T. E., and DOUGLASS, H. L. (1938), *J. Urol.*, **40**, 506.

REVIEWS AND NOTICES OF BOOKS

Surgical Care. A Handbook of Pre- and Post-operative Treatment. By R. W. RAVEN, F.R.C.S., Major, R.A.M.C., late Surgeon, E.M.S.; Assistant Surgeon, Royal Cancer Hospital; etc. $7\frac{1}{4} \times 4\frac{7}{8}$ in. Pp. 271 + viii, with 80 illustrations. 1942. London: Edward Arnold & Co. 10s. 6d. net.

THE decentralization of our hospital system since the war has imposed greater responsibility upon the junior, and increasing strain upon the senior members of the surgical profession in the detailed supervision of their work. This is a situation far from ideal as far as surgery is concerned because pre- and post-operative treatment is very much a matter of personal habit and experience.

However, Major Raven, in his handbook, has wisely bridged the gap by discussing the problem in some thirty-five chapters devoted to the routine care of the cases from the point of view of regional surgery.

This book commends itself not only to Registrars and House Officers, but to the nursing staff in the ward and in the theatre, and gives clear and incisive details for the necessary procedures to be adopted for the various investigations in which different departments are concerned, as well as the more important methods of treatment both before and after operation.

Textbook of Surgical Treatment. Including Operative Surgery. Edited by C. F. W. ILLINGWORTH, M.D., Ch.M., F.R.C.S.E., Regius Professor of Surgery, University of Glasgow. Compiled by Eighteen Contributors. $9\frac{3}{4} \times 6\frac{1}{8}$ in. Pp. 528 + xii, with 144 illustrations. 1942. Edinburgh: E. & S. Livingstone. 28s. net.

THIS book is intended mainly for senior students and those undergoing training in surgery; it aims at a different approach to the subject of surgical treatment from that provided by a text-book of operative surgery by the inclusion of fuller accounts of the pre-operative and post-operative measures necessary to promote the full recovery of the patient. The underlying idea is manifestly a good one provided that it does not lead the student to concentrate on treatment to the exclusion of pathology and diagnosis, and it has to a large extent been carried through successfully. The subject-matter is arranged on a general and regional basis, and the editor has evidently taken great care to avoid any overlapping by the different contributors. To some extent this is a disadvantage; for example, whilst the treatment of recurrent dislocation of the shoulder is discussed in the chapter on affections of the shoulder region, that of dislocation of the shoulder is found in the chapter on fractures. The former account is a good one, but we should prefer a correct spelling of the name of Bankart in the description of his operation. One of the best chapters is that on affections of the skull and brain, and the account of the management of head injuries will give the student a better idea of the subject than that conveyed by many text-books.

Our only point of difference is with the advocacy of an indwelling catheter for retention of urine, for it is now generally admitted that this is the certain cause of serious urinary tract infection. There are some surprising omissions for a book purporting to deal with surgical treatment in general; there is no mention of fractures of the pelvis, a subject with which every prospective surgeon should have some acquaintance. Nor can we find any account of the methods used to attempt prevention of recurrent urinary stone formations, although the actual removal of stones from the kidney, ureter, and bladder is well described. Such points as these are, perhaps, of minor importance, and can be repaired in a second edition; they do little to detract from the general utility of the book as a clear and concise account of surgical treatment.

The Surgery of Pancreatic Tumours. By ALEXANDER BRUNSCHWIG, M.S., M.D., F.A.C.S., Professor of Surgery, University of Chicago. Illustrated by GLADYS MCHUGH. $10 \times 6\frac{7}{8}$ in. Pp. 421, with 124 illustrations. 1942. London: Henry Kimpton. 37s. 6d.

MODERN surgery is gradually overcoming all obstacles in its advance and probably the pancreas is the last organ on which successful surgical excision has been performed. Professor Brunschwig, of Chicago, has put the surgical profession in his debt in producing such a comprehensive and informative volume on the surgery of pancreatic tumours. Tumours of the head of the pancreas and of the papilla of Vater are not uncommon and should be subjected to surgical excision far more frequently than they are at present. Pancreatic cysts are quite suitable for surgical treatment and yet too often they are neglected until their size and connexions make operation difficult.

This book should do a great deal to stimulate surgeons all over the world to endeavour to deal with pancreatic tumours on modern surgical lines. It will prove valuable as a reference book and as such will be of use to both physicians and surgeons.

Modern Operative Surgery (Carson's). Edited by G. GREY TURNER, LL.D., D.Ch., M.S., F.R.C.S., F.R.A.C.S., F.A.C.S., Professor of Surgery in the University of London and Director of Surgery at the British Post-graduate Medical School, etc. In two volumes. Vol. I. $9\frac{1}{4} \times 6\frac{1}{8}$ in. Pp. 1041 + xvi, with 504 illustrations. 1943. London: Cassell & Co. Ltd. 50s. net.

OPERATION technique is but a small part of surgery. Experience alone can teach when certain procedures should and should not be undertaken, and how difficulties and dangers may be met and overcome; yet a good text-book of operative surgery may go far in guiding the young surgeon towards winning this experience, to some extent providing it ready-made. *Modern Operative Surgery* in its previous editions established its claim to this achievement, and the third edition has been compiled with the same objective in view.

This first volume is larger than its predecessors, and closer inspection shows that as well as the addition of much new material, there has been thorough revision of all sections; some have been almost completely rewritten, without upsetting the general pattern of the work. The preface gives the names of certain new contributors, but does not mention Lambert Rogers, the only newcomer to this volume, who has redone the chapter on the Surgery of the Spinal Cord, a most satisfying contribution.

The thorough and painstaking labour of the editor is evident throughout the work, and the numerous chapters for which he is solely responsible amply justify the dedication of this edition to the memory of his master, Rutherford Morison. It has ever been his desire to advise and encourage young surgeons, and to help them in the management of their problems. Hence the stress placed upon pre-operative preparation and post-operative care, which is well exemplified in the chapter on the surgery of the biliary system. Here, as elsewhere in the volume, due regard has been paid to recent advances in physiology and biochemistry in their bearing upon surgery.

Many of the chapters originally written by H. W. Carson, and revised in the second edition, have now been completely re-written and amplified, and the new illustrations and the general standard of the production have not suffered as a result of the many difficulties which must have been experienced in bringing out such a book at the present time.

There is very little that calls for adverse criticism. The excellent chapter on the surgery of joints ought to include a description of the exposure of the temporo-mandibular joint from behind; the important problems connected with secondary hæmorrhage deserve much fuller consideration; and certain well-known procedures of great historical interest, now but little used, seem rather out of place in a text-book of modern operative surgery. These are minor points, and those who had learnt to look to "Carson" for help in examinations, and in practice, will accept the present work as a worthy successor, and will look forward in happy and confident anticipation to the appearance of its companion volume.

Urology in War. Wounds and Other Emergencies of the Genito-urinary Organs, Surgical and Medical. By CHARLES Y. BIDGOOD, Lt.-Comdr. (M.C.) U.S.N.R., Chief Urologist, U.S. Naval Hospital, Washington, D.C. 9 × 6 in. Pp. 78 + ix, with 27 illustrations. 1942. Baltimore: The Williams & Wilkins Co. (London: Baillière, Tindall & Cox.). 11s. net.

THE laudable desire to present in a convenient form a concise account of the urological emergencies which may confront a medical officer under war conditions has evidently prompted the author to write this book. Read in this light it will serve a useful purpose, but those who expect to find in it an adequate account of the surgery of war wounds of the urinary tract will be disappointed. It fails in this respect because it deals solely with the genito-urinary organs and lays insufficient emphasis on the fact that wounds of these organs seldom occur alone. The main sections deal with traumatic and inflammatory lesions of the genito-urinary tract; there is a chapter on bladder dysfunction after spinal injury by Dr. Lloyd G. Lewis in which he advocates no catheterization for the first 48 hours, a policy with which most surgeons will now agree. There will be less unity on the need for catheterization after this period and on the avoidance of suprapubic cystotomy unless there is infection. The section on anæsthesia occupies nearly a quarter of the book.

The illustrations, many of which have appeared before, are good, but there are many misprints in the text. The book will prove attractive to those who like their information condensed.

BOOK NOTICES

[*The Editorial Committee acknowledge with thanks the receipt of the following volumes. A selection will be made from these for review, precedence being given to new books and to those having the greatest interest for our readers.*]

Synopsis of Traumatic Injuries of the Face and Jaws. By DOUGLAS B. PARKER, M.D., D.D.S., Associate Professor, Department of Oral Surgery, School of Dental and Oral Surgery, Columbia University. 7⅝ × 5 in. Pp. 334, with 229 illustrations. 1942. London: Henry Kimpton. 22s. 6d. net.

Sea Diseases. The Story of a Great Natural Experiment in Preventive Medicine in the Royal Navy. By R. S. ALLISON, V.D., M.D., F.R.C.P. With a Foreword by SHELDON DUDLEY, C.B., O.B.E., F.R.S., M.D., F.R.C.P., K.H.P. 8⅝ × 5⅜ in. Pp. 218 +xxiii, with 12 illustrations. 1943. London: John Bale Medical Publications Ltd. 25s. net.

First Aid in the Royal Navy. 7⅛ × 4¾ in. Pp. 106, with 63 illustrations. 1943. London: H.M. Stationery Office. 2s. net.

Rose and Carless Manual of Surgery. For Students and Practitioners. By CECIL P. G. WAKELEY, C.B., D.Sc., F.R.C.S., F.R.S.E., F.R.S.A., F.A.C.S., F.R.A.C.S., Senior Surgeon, King's College Hospital, London, etc.; and JOHN B. HUNTER, *M.C.*, M.Chir., Cantab., F.R.C.S. Eng., Surgeon, King's College Hospital, etc. Seventeenth edition. In two volumes. 8¾ × 5⅝ in. Vol. I, pp. 840 + xx, with 501 illustrations and 10 plates; Vol. II, pp. 926, with 599 illustrations and 20 plates. 1943. London: Baillière, Tindall & Cox. 35s. net.

Renal Lithiasis. By CHARLES C. HIGGINS, M.D., Cleveland Clinic, Ohio. 7½ × 5 in. Pp. 140 + xii, with 18 illustrations. 1943. Springfield, Ill.: Charles C. Thomas. $3.00.

The Students' Handbook of Surgical Operations. By Sir FREDERICK TREVES, Bart., G.C.V.O., C.B., LL.D., F.R.C.S. Seventh edition, revised by CECIL P. G. WAKELEY, C.B., D.Sc., F.R.C.S., F.R.S.E., F.A.C.S. (Hon.), F.R.A.C.S., Fellow of King's College, London; Senior Surgeon to King's College Hospital; etc. 7⅛ × 4¾ in. Pp. 562 + xii, with 265 illustrations. 1943. London: Cassell & Co. 12s. 6d. net.

War Wounds and Injuries. Edited by R. MAINGOT, F.R.C.S., E. G. SLESINGER, O.B.E., M.S., F.R.C.S., and ERNEST FLETCHER, M.A., M.B., M.R.C.P. With a Foreword by Lord HORDER. Second edition. 8⅜ × 5⅜ in. Pp. 499, with 119 illustrations. 1943. London: Edward Arnold & Co. 35s. net.

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